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Meeting Minutes Transmittal/Approval
Unit Managers' Meeting
100 Area Remedial Action and Waste Disposal Unit/Source Operable Unit
3350 George Washington Way, Richland, Washington
July ~~August~~ 2000

APPROVAL: ______________________ Date 8/24/00
Glenn Goldberg/Chris Smith, 100 Area Unit Managers, RL (H0-12)

APPROVAL: ______________________ Date 8-24-00
Wayne Soper, 100 Aggregated Area Unit Manager, Ecology (B5-18)

APPROVAL: ______________________ Date 8-24-00
Dennis Faulk, 100 Aggregate Area Unit Manager, EPA (B5-01)

APPROVAL: ______________________ Date 8-24-00
Rick Bond, 100-N Area Unit Manager, Ecology (H0-18)

Meeting minutes are attached. Minutes are comprised of the following:

Attachment 1	--	Attendance Record
Attachment 2	--	Agenda
Attachment 3	--	100 Area Meeting Minutes
Attachment 4	--	Unit Manager's Meeting 10 Area COPC/COC Development Process
Attachment 5	--	Approved CVPs
Attachment 6	--	Appendix B – Summary of Data Analysis of the 100 Area CVP Confirmation Data
Attachment 7	--	Underground Radioactive Waste Sites (maps)
Attachment 8	--	Well Summary Sheet
Attachment 9	--	Backfill Concurrence Checklist (116-DR-4 Pluto Crib)
Attachment 10	--	Backfill Concurrence Checklist (116-D-6 Liquid Disposal Trench)
Attachment 11	--	Signed Approval Version of the 100-NR-2 Waste Management Plan
Attachment 12	--	NR Data Quality Objectives Summary

Prepared by: Tamen Rodriguez Date 8/29/00
Tamen Rodriguez (H0-17)

Concurrence by: Date Aug 30, 2000
Vern Dronen, BHI Remedial Action and Waste Disposal Project Manager
(H0-17)

Remedial Action and Waste Disposal Unit Manager's Meeting
Official Attendance Record
July 20, 2000

Please print clearly and use black ink

PRINTED NAME	ORGANIZATION	O.U. ROLE	TELEPHONE
Buckmaster, MA	Group 4	Eng	521-2087
John April	RAWD	Task Lead	2-9632
Frank Corpuz	RAWD	Proj Engr	531-0675
Wayne Soper	Ecol	OU	736-3049
Larry Gadbois	EPA		376-9884
Glenn Goldberg	DOE	Proj. Manager	376-9552
Arlene Tortoso	DOE	100 Area GW	373-9631
JON YERXA	DOE	ORL	376-9628
Rick Bond	Ecy	100-N	736-3007
Dennis Faulk	EPA		

Attachment 1

Remedial Action and Waste Disposal Unit Manager's Meeting
Official Attendance Record
July 20, 2000

Please print clearly and use black ink

PRINTED NAME	ORGANIZATION	O.U. ROLE	TELEPHONE
Roger Ovink	CHI		372-9631
Ella Cronenberg	CHI		372-9303
KE Cook	CHI		372-9363
FRED ROECK	BHI	PEL	372-9565
Ray Brown	CHI		372-9622
Mark Striges	ERC		531-0679
Tim Lee	CHI	GW	372-9362
A L Langstaff	BHI	BC&D Testbed	373-5876
Jon Fancher	CHI	ION. E.L.	531-0701
Steven Clark	CHI	CVP	372-9531
Ralph Wilson	CHI	CVP	375-9432
Rick Donahoe	BHI		372-6230

UNIT MANAGERS MEETING AGENDA

3350 George Washington Way, Room 1B45
July 20, 2000

<u>1:00 – 3:00 p.m</u>. <u>100 Area</u> <u>1B45</u>

General

- Status of 100 Area SAP/RDR Rev. 2 Comment Response/Resolution
- Status of Comments on Sampling and Analysis Plan for 100 Area Remaining Sites
- 100 Area Burial Grounds ROD Status
- Five year ROD Review Status
- Process of Determination of COPC/COC's Used in the 100 Areas
- CVP Update
- "Deviations from MTCA" Meeting Minutes
- Burial Ground Public Comments – Draft Responses

100 H, F and K, Group 4

- 100-H-2 Burial Pit Location
- 100-H Status
- 100-F Status
- 100-H-17 Sampling Strategy
- 100-H-2 (Replace 100-H-1 with 100-H-2 in TPA milestone site count)
- Cleanup Verification Sampling Status

100N

- Status of Remediation
- 100-N-1 Air Monitoring Plan
- "Contained In" Determination
- 100-NR-1 Source Site ROD – Petroleum Site Remediation
- 100-N-3 Trench – Unused End of Trench Cleanup Verification Activities

100-B/C and D

- 100 DR - Proposed Air Monitor Shut Off/Walkdown with Ecology and DOH
- 100 B/C - Review of B/C Pipeline Procurement Status
- Setup Meeting to Discuss TPA Milestone Revision (M-16-26B)

Groundwater

- Status Update for the Ground Water Operable Units

UNIT MANAGERS MEETING AGENDA

3350 George Washington Way, Room 1B40
July 20, 2000

Meeting Attendance Sheet – Attachment 1

Meeting Agenda – Attachment 2

Meeting Minutes – Attachment 3

1:00 – 3:00 p.m. 100 Area 1B45

General

- Status of 100 Area SAP/RDR Rev. 2 Comment Response/Resolution – ERC (John April and Steve Clark) briefly reviewed the EPA and Ecology comments on the *Remedial Design Report/Remedial Action Work Plan for the 100 Area* ((DOE/RL-96-17, Rev. 1) (RDR/RAWP) and *100 Area Sampling and Analysis Plan* (DOE/RL-96-22, Rev. 1) (SAP). EPA (Dennis Faulk) and Ecology (Wayne Soper) had both submitted a comment regarding the apparent incongruity of the high constituent kd value and low 100x rule value. Both agreed that ERC could address this comment using a footnote in the document. ERC (John April) stated that the revised documents would be sent to the regulators electronically for their approval prior to formal document revision.

- Status of Comments on Sampling and Analysis Plan for 100 Area Remaining Sites – ERC (John April) stated that EPA and Ecology comments are being received on the *Sampling and Analysis Plan for the 100 Area Remaining Sites* (DOE/RL-99-58, Draft A). The document will be discussed at a future Unit Manager Meeting when the comments have been addressed.

- 100 Area Burial Grounds Record of Decision (ROD) Status – ERC (John April) provided EPA with draft responses to public meeting comments on the Proposed Plan. EPA (Dennis Faulk) briefly discussed the changes needed in the associated focused feasibility study, in order to agree with the 100 Area Burial Grounds Proposed Plan.

- Five Year ROD Review Status – EPA (Larry Gadbois) discussed the current review of five years of work conducted under the ROD. The 5 Year Review looks at the progress at different ERC 100 Areas activities such as remedial action, decontamination and decommissioning, and pump and treat operations. The review focuses on work progress, whether the work has been appropriately protective on the environment and groundwater, and if any changes need to be made in the planned activities to more effectively perform the work. EPA will distribute the draft report to attendees for review.

- Process of Determination of COPCs/COCs Used in the 100 Areas - ERC (Roy Bauer) discussed a handout (Attachment 4) outlining the process for developing Contaminants of Potential Concern (COPCs) and Contaminants of Concern (COCs). Based on the evolving methodology for determining COC lists, the key to accurate lists has been flexibility. EPA (Dennis Faulk) stated that the table development rationale needs to be included in the appropriate SAP document, to which ERC agreed. ERC will e-mail EPA revised SAP text to reflect this change.

- CVP Update – ERC (Ralph Wilson) provided the current schedule (Attachment 5) of Cleanup Verification Package (CVP) document review and approval dates. ERC will provide Ecology with a recalculated 116-D-7 RESRAD brief for review, and will revise the CVP document for the 116-D-7 site to reflect the revised calculations. ERC also provided Ecology (Wayne Soper) with five CVP documents for review:

CVP-2000-00001 100-D-18
CVP-2000-00002 116-DR-1&2
CVP-2000-00004 1607-D2 Pipelines
CVP-2000-00005 100-D-48:2/49:2 D & DR Group 2 Pipelines
CVP-2000-00019 116-DR-7

- "Deviations from MTCA" Meeting Minutes – ERC (Fred Roeck) briefly discussed a 7/05/00 meeting with EPA and Ecology regarding deviation from Model Toxic Control Act (MTCA) guidance in CVP documents. The meeting minutes, ERC correspondence control number 080652 (Attachment 6), were reviewed and agreed to by EPA and Ecology.

- Burial Ground Public Comments – Draft Responses – discussed above, under 100 Area Burial Grounds Record of Decision (ROD) Status.

100 H, F and K, Group 4

- 100-H-2 Burial Pit Location – ERC (Mark Buckmaster) provided a handout (Attachment 7) regarding the continued efforts to determine the actual location of the site. ERC has checked the historical information and identified possible locations, but so far the site location has not been found. ERC proposed that based on the inconclusive site search results, to stop looking at this time. Ecology (Wayne Soper) will look at the background information on this issue, and schedule a subsequent meeting with ERC to discuss issue further.

- 100 H Status – ERC (Mark Buckmaster) stated that the removal of additional contaminated material is currently being performed at H Area. The excavation work should be completed by the end of July as mobilization to the 100 F Area ramps up.

- 100 F Status - ERC (Mark Buckmaster) reported that the mobilization from 100 H to 100 F is in progress. The bulk of the trailer and equipment mobilization is scheduled to occur in the last week of July, with production beginning in August. Currently, overburden removal is underway.

- 100-H-17 Sampling Strategy – ERC (Mark Buckmaster) verified for Ecology (Wayne Soper) that the sampling strategy previously discussed for this site (discussed in the March and April 100 Unit Manager Meeting minutes) would be implemented. Ecology concurred with the sampling strategy.

- 100-H-2 (Replace 100-H-1 with 100-H-2 in TPA milestone site count) – ERC (Mark Buckmaster) discussed the plan to replace 100-H-1 with 100-H-2 in the Tri-Party Agreement milestone site count. This substitution would maintain the 10 total of sites shown for the Group 4 100 H milestone.

- 116-H-1 Preliminary Borehole Results (New Item) – ERC (Mark Buckmaster) provided a handout on the preliminary results (Attachment 8), with a final report to follow at a later date. The preliminary borehole results showed only background moisture in the borehole. The lack of additional moisture below ground level indicates that dust control water has not infiltrated below the surface and caused contamination problems. The data also indicates contamination penetrating a couple of meters below the bottom of the trench.

100 N

- Status of Remediation – ERC (Jon Fancher) stated that the 100 N Readiness Review was completed satisfactorily on 7/20/00. On 7/21/00, ERC gave the subcontractor written Notice To Proceed with remediation activities. Preliminary analytical sampling has verified that the initial materials removed all meet the acceptance criteria for the ERDF facility.

- 100-N-1 Air Monitoring Plan – ERC (Ella Coenenberg) stated that the Air Monitoring Plan for the 116-N-1 Crib and Trench is being prepared, and will be provided to Ecology (Rick Bond) for approval.

- "Contained In" Determination – ERC (Jon Fancher) stated that the draft strategy would be provided to Ecology (Rick Bond) in about two weeks.

- 100-NR-1 Source Site ROD – Petroleum Site Remediation – EPA (Dennis Faulk) stated that the ERDF facility could accept waste containing petroleum. The N Area site containing petroleum was inadvertently included in the ROD for the remediation activities. ERC (Rick Donahoe) added that the site containing petroleum waste would be addressed in the scope of the remedial activities at 100 N.

- 100-N-3 Trench – Unused End of Trench Cleanup Verification Activities – ERC (Jon Fancher) stated that the cover panels need to be kept on this portion of the trench at this time. Analytical sampling will need to be conducted, pending approval of the strategy from Ecology.

- Dust Control Water Measurements (New Item) – ERC (Jon Fancher) proposed to measure the number of water truck loads used for dust control during a six month period at 100 N. ERC would like to use the resulting information to measure for possible mobile soil contamination by the application of the water. The dust control water usage could be examined in conjunction with 100 N monitoring well information. DOE (Arlene Tortoso) stated that the groundwater monitoring well activities could be coordinated with the 100 N dust water usage study.

100 B/C and D

- 100 DR - Proposed Air Monitor Shut Off/Walkdown with Ecology and DOH – ERC (Alvin Langstaff) stated that a walkdown of the Group 2 groundwater monitors would be conducted in the next couple of weeks.

- 100 B/C - Review of B/C Pipeline Procurement Status – ERC (Alvin Langstaff) stated that the Request For Proposal document for the pipeline work was being finalized.

- Setup Meeting to Discuss TPA Milestone Revision (M-16-26B) – ERC (Alvin Langstaff) took the action to provide EPA (Dennis Faulk) with a draft package reflecting the milestone revision.

- The approved Backfill Concurrence Checklist forms for 116-DR-4 Pluto Crib (Attachment 9) and 116-DR-6 Liquid Disposal Trench (Attachment 10) were entered in to the meeting minutes.

Groundwater

- Status Update for the Groundwater Operable Units – DOE (Arlene Tortoso) discussed the 100-NR-2 Waste Management Plan (Attachment 11), which received approval signatures. The status of the individual Groundwater Operable Units was discussed. In general, the Groundwater activities were on schedule. The In-Situ Redox Unit is scheduled for injection treatments, to begin in about two weeks. The first borehole was completed at the In-Situ Gaseous Reduction Unit, showing no hexavalent chromium contamination as previously indicated by water analysis.

- DOE (Glenn Goldberg) stated that the NR Data Quality Objectives summary (Attachment 12) would be distributed as an attachment via these meeting minutes.

UNIT MANAGER'S MEETING
100 AREA COPC/COC DEVELOPMENT PROCESS

Overview

- The COPC/COC selection process has evolved over time with the various waste site groups according to project needs
- Primary variables that affected the selection processes were the availability of site-specific data and regulatory documents

History

- Group I/Group II Sites

  - Contaminants found in waste sites were based on the ROD, LFI, Technical Baseline Reports, FFS, process knowledge, the ERDF Source Inventory Engineering Study, Dorian and Richards

  - Contaminants found – Exclusions = COCs

  - Group II had an additional refinement that drove the reduction of COC lists by an ERC directive. It required analytical costs to be maintained < 8% of the total remedial action budget.

- Group III/Group IV Sites

  - COPC lists were based on lessons learned, HEIS, WIDS, historical data, and selected application of analogous site assignments.
  - Field investigations at selected sites with little or no process knowledge for waste profile inputs
  - Group III/IV sites established specific exclusion logic
  - Tabulations were developed for each site to document the retention or exclusion of COPCs, yielding a COC list for each site
  - If process knowledge or analogous information was used, contaminants were identified and retained as COPCs.

- Remaining Sites

  - These low risk sites have little or no site investigation or historical data.
  - COPC lists were developed from analogous site determinations from process knowledge.
  - Refinements of the COPC lists were generally limited to short-lived radionuclide exclusions.
  - The COPC designation was retained because of the absence of site-specific data.

- Lessons Learned

  - Regulators requested expansion of the COPC/COC list during closeout verification sampling at the 116-C-1 Liquid Effluent Disposal site, by inclusion of Ni-63 and Pb at depth below the engineered excavation plan.
  - Analysis showed the presence of Ni-63 and Pb at depth
  - COC lists have been expanded during 100 Area waste site closeout verification sampling, to include H-3, Ni-63, Tc-99, and Pb on a case-by-case basis, when supported by process knowledge and analogous site information.
  - COPC/COC are considered a starting point in the cleanup process and are always subject to additions/deletions consistent with the observational approach employed by ERC.

APPROVED CVPs

Site Designation	Site Type	EPA/Ecology Signoff on WIDS Form	Processed by ERC WIDS Group
BC Group 3 Sites			
116-B-8	Basin Sludge Burial Pit	7/22/99	Complete
116-B-5	Crib, Trench	1/8/97	Complete
116-B-13	South Sludge Trench	7/22/99	Complete
116-B-14	Trench	7/22/99	Complete
116-C-1	Retention Basin	1/21/99	Complete
116-B-1	Trench	12/8/99	Complete
116-B-11	Retention Basin	12/8/99	Complete
116-C-5	Retention Basin	12/8/99	Complete
116-B-4	French Drain	2/24/00	Complete
116-B-6B	Crib	2/24/00	Complete
116-B-9	French Drain	2/24/00	Complete
116-B-2	Fuel Storage Basin Trench	2/24/00	Complete
116-B-3	Crib	2/24/00	Complete
116-B-10	Dry Well	2/24/00	Complete
116-B-12	Crib	2/24/00	Complete
116-C-2A/B/C & OB	Crib/Pump Station	3/15/00	Complete
116-B-6A/B-16	Crib/Storage Tanks	5/17/00	Complete
D/DR Group 2 Sites			
120-D-1	100-D Ponds	8/27/99	Complete
100-D-4 (107D5)	Sludge Pit	3/25/99	Complete
100-D-20 (107D3)	Sludge Pit	3/25/99	Complete
100-D-21 (107D2)	Sludge Pit	3/25/99	Complete
100-D-22 (107D1)	Sludge Pit	3/25/99	Complete
1607-D-2	Septic Tank	11/23/99	Complete
1607-D2:1	Abandoned Tile Field	3/25/99	Complete
100-D-25	Unplanned Release	1/6/99	Complete
116-DR-9	Retention Basin	1/6/00	Complete
D/DR Group 2 Pipelines			
100-D/DR	Group 2 Pipeline Overburden Piles	3/30/00	Complete
D/DR Group 3 Sites			
116-D-3	French Drain	04/06/00	Complete
D/DR Group 3 Pipelines			
H Group 4 Sites			
116-H-6	Solar Evaporation Basins	5/13/97	Complete
F Group 4 Sites			

Status Date: 7/20/00 10:53 AM

080652

Job No. 22192
Written Response Required: NO
Due Date: N/A
Actionee: N/A
Closes CCN: N/A
OU: N/A
TSD: N/A
ERA: N/A
Subject Code:

Environmental Restoration Contractor **ERC Team**

Meeting Minutes

SUBJECT CLOSEOUT VERIFICATION PACKAGE, DEPARTURES FROM MTCA GUIDANCE

TO Distribution

FROM FV Roeck FVR

DATE July 6, 2000

ATTENDEES

M. A. Buckmaster X9-10 (BHI)
F. M. Corpuz X5-60 (BHI)
D. D. Faulk B5-01 (EPA)
G. I. Goldberg H0-12 (DOE)
A. L. Langstaff X9-06 (BHI)
F. V. Roeck H0-17 (BHI)
W. W. Soper B5-18 (Ecology)
J. W. Yokel B5-18 (Ecology)

DISTRIBUTION

Attendees
P. G. Doctor H0-23
M. R. Schwab H0-18
B. L. Vedder H0-02
R. C. Wilson H9-02
Document and Information Services H0-09

A meeting on the above subject was held on July 5, 2000, at 3350 GWW, Room 2B32.

The meeting was held to discuss how and why certain sampling and statistical methods used to support 100 Area cleanup verification packages (CVPs) differ from methods presented in the Model Toxic Control Act (MTCA) *Statistical Guidance for Ecology Site Managers*. A summary handout (attached) was provided outlining the two areas where the 100 Area CVP process departs from the MTCA Guidance. Attendees were provided the summary and supporting "white paper" (attached) prior to the meeting. Time was taken for individuals to review the handout.

BHI opened the meeting by presenting the purpose and scope of the meeting. The stated purpose was to gain acknowledgement from the Tri-Parties that they have a common understanding of the CVP process as it relates to the MTCA Guidance.

A BHI assessment of the Guidance was done in the expectation that it will promulgated into the Washington Administrative Code, possibly in the near future. The Guidance permits deviations, provided the deviations are technically justified and approved by the agency. The 100 Area remedial action documentation for the site closeout process is contained in the RDR/RAWD, SAP and CVP reports. Collectively, these documents outline the process which is used for the evaluation and closeout of waste sites and are signed by the regulators. However, there is no single location whereby departures from the Guidance are documented. The meeting handout and "white paper" were intended to provide that documentation.

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EPA stated that the promulgated guidance would not be considered ARAR under the current process. The attendees acknowledged this observation. BHI expressed an obligation to evaluate new regulations to determine if they are more protective of human health and the environment and should be considered ARAR.

Following the discussion of the purpose of the meeting and reasons for conducting the evaluation, the meeting was opened for discussion. Ecology (J. Yokel) stated the documentation provided a clear presentation of the Guidance and the departures. With regards to the guidance discussion on dilution of composite sampling, Ecology stated the iterative process of field screening, sampling, and performing additional excavation as necessary was conducive to evaluating radionuclides. However, this is not necessarily the case for non-radioactive contaminants. No specific process is formalized for evaluating or taking into account the affects of composite for non-radioactive contaminants.

A discussion of the methods used to evaluate non-radioactive contaminants focused on site-specific variations in how certain contaminants are assessed on a case-by-case basis. EPA stated that the current process to evaluate non-radioactive contaminants employs best engineering judgement in the field. BHI asked whether a process improvement evaluation should be conducted to assess possible enhancements to the non-radadionuclide contaminant screening and sampling methods for possible inclusion in the 100 Area documentation. Following a short discussion, the parties agreed that the current process of using best engineering judgement and working with the lead regulatory agency was adequate and further refinement was not necessary and may be difficult to proceduralize.

It has been postulated in the 100 Area documentation that non-radioactive contaminants should, within certain limitations, behave similarly to radioactive contaminants in the environment. Therefore, the process used to evaluate radioactive contaminants would be used to identify the distribution of non-radioactive contaminants as well. However, no definitive evaluation has been conducted to verify this assumption. The attendees reasoned that there was likely to be at least a loose correlation between contaminant distribution since the CVP process has been effective in identifying site-specific COCs. It was concluded that an evaluation should be conducted to determine if a correlation exists between the distribution of certain radioactive and non-radioactive contaminants. BHI (F. Corpuz) took the action to lead the evaluation.

In regards to the MTCA lognormal distribution assumption, all parties agreed that the described 100 Area methodology was acceptable. Ecology did, however, state that when evaluating very small sites the 100 Area CVP process may not be as effective. EPA indicated that the remaining sites SAP proposes a different approach to field screening and sampling that was more appropriate for evaluating the smaller sites. Neither agency has yet reviewed the remaining sites SAP.

The meeting was closed by reiterating the Tri-Parties acknowledged the CVP process and had a common understanding of the departures from the MTCA Guidance. Their acknowledgement would be provided in the form of these meeting minutes and be documented as part of the next 100 Area Unit Managers Meeting.

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100 AREAS CLEANUP VERIFICATION METHODOLOGY: DEPARTURES FROM ECOLOGY GUIDANCE

Topic: Composite Sampling

What does MTCA Guidance say to do?

- MTCA's Statistical Guidance for Ecology Site Managers discusses some advantages and disadvantages of compositing.
  The advantages cited are that compositing may be useful for:
  - screening a large area
  - evaluating risk for an area where people are expected to be exposed.

  Disadvantages or problems include:
  - overlooking a "hot spot" due to the diluting effect of compositing
- MTCA Guidance on Sampling and Data Analysis Methods, states that:
  - "Although compositing may be used for making decisions on the need for remediation, it may not be used after remediation to determine whether cleanup standards have been met."
  - Due to the "diluting" effect of compositing, a "screening level" criterion should be used instead of the Action Level. This screening level criterion is calculated by dividing the Action Level by the number of samples combined to make the composite.

What does the 100 Area Remedial Action Project do?

- The 100 Area Sampling & Analysis Plan and Instruction Guide outline the following procedure:

  In-process and hot spot screening
  - During remediation, perform radiation screening and collect "in-process" samples (where appropriate) to indicate when a site may be clean
  - When in-process results indicate the site may be clean, perform field screening for hot spots within each of the three decision units (shallow zone, deep zone, and overburden).
  - If no hot spots are detected, divide the decision units into 1 or more decision subunits depending on the size of the decision unit.

  Variance sampling
  - Divide each subunit into sample areas (4 each for shallow zone and overburden, 3 for deep zone).
  - Further divide each sample area into 16 sample nodes.
  - To support variance sampling, randomly select 6 sample nodes from the shallow zone and overburden sample areas (minimum of 24 each). These are the "variance" sample points.
  - Acquire variance samples from the selected sample nodes and test for gamma-emitting radionuclides and/or, where appropriate, other constituents. Variance samples are *not* composited.
  - Compare variance sample results to the remedial action goals; if it appears the site is not yet clean, resume excavation and then resample. Repeat until the site appears to be clean.

  Verification Sampling
  - When variance sample results indicate the site is clean, use the results to determine the population variance for the decision unit.

- Using this variance, compute the number of final verification samples required.
- The default minimum number of verification samples is 4 for the shallow zone and overburden decision units, and 3 for the deep zone decision unit. If the computed required number of verification samples is less than the default number, plan to collect the default number. If the computed number is greater than the default number, plan to collect the computed number or resume excavation and start the process over.
- To proceed with verification sampling, select 4 sample nodes within each sampling area. Collect an aliquot of soil from each of the four nodes and composite these to create the cleanup verification sample for that sampling area.
- Doing this for each sampling area results in a minimum of 3 (deep zone) or 4 (shallow zone and overburden) composited samples per decision unit.
- Perform laboratory analyses for all relevant COCs for the site.

<u>Cleanup verification</u>

- Upon receipt of analytical data, a statistical evaluation (i.e. the 95% UCL) is performed over data from the entire decision unit (e.g., the entire shallow zone) rather than for each subunit within the decision unit.
- For nonradionuclides, in general terms, the 95% UCL computed for each decision unit (e.g., shallow zone) is compared to the applicable remedial action goals (RAGs).
- For radionuclides, in general terms, the 95% UCL for each decision unit is entered into the RESRAD model to estimate the maximum total radiation dose for comparison to the RAG (e.g., 15 mrem/yr. in shallow zone and overburden).

What are the important differences?

- The 100 Area projects use composite sample results to make final cleanup verification decisions.
- The 100 Area projects use the Action Level (RAG) as is and do not calculate a screening level criterion.

What is the potential impact of these differences?

- If the site is "clean" the impacts of the departures are minimal.
- However, if the site is not "clean" then both compositing and using the Action Level in lieu of the screening level criterion increases the likelihood of incorrectly deciding that a dirty site is clean.

What does a review of the process indicate?

- The impacts of these departures are considered minimal given the multi-phased observational approach used to test the sites using both field screening and laboratory analytical methods.
- If individual variance sample results (non-composited) indicate that the RAGs are not met in some portion (or all) of the excavation, then excavation is continued. Upon removal of one or more additional lifts, additional variance samples are collected and analyzed. This process is repeated until both in-process screening data and the non-composited variance sampling results indicate the site is clean. All this happens before *any* verification samples are collected.
- Published EPA guidance on hot spot criteria indicates that the largest size of the 100 Area cleanup verification sampling area falls well within recommended size limitations for hot spot evaluations in a residential scenario.

Topic: Lognormal Distribution Assumption

What does MTCA Guidance say to do?

- Begin with the assumption of lognormality.
- If the assumption of lognormality cannot be rejected, used Land's method to calculate the 95% UCL.
- If the assumption of lognormality can be rejected, test the assumption of normality.
- If the assumption of normality cannot be rejected, calculate the 95% UCL using t or Z for large sample populations (n > 20).
- If both lognormality and normality cannot be rejected for small sample populations (n < 20), the lognormal distribution should be used.
- If the assumption of normality can be rejected, use a nonparametric method to calculate the 95% UCL.
- Alternatively, more samples can be taken to better determine the distribution.

What does the 100 Area Remedial Action Project do?

- For data sets where n > 10, MTCA guidance is followed.
- For data set where n < 10, a nonparametric method applicable to any distribution is used.

What are the important differences?

- MTCA defines a small data set as n < 20, while the Project defines a small data set as n < 10.
- When the sample size is less than 10, distributions are not tested and a nonparametric method is used for calculating the 95% UCL (the MTCA Statistical Guidance states that this method may be used to approximate a 95% UCL when sample population sizes are small, but simultaneously cautions against it).

What is the potential impact of these differences?

- When the sample population size is small, it can be difficult to determine the distribution of the population from which the sample was drawn. Making an invalid assumption about the population distribution, and consequently using an inappropriate calculation method, can introduce bias into the result, however the magnitude and direction of the bias cannot be determined.

What does the data analysis show?

- An analysis of both randomly-generated lognormal data and the actual 100 Area cleanup verification data indicates there is no evidence of bias for the small sample population sizes.
- The 95% UCLs for the nonparametric method (as well as the ones based on the t distribution) were notably consistent regardless of sample population size.

100 AREAS CLEANUP VERIFICATION METHODOLOGY: DEPARTURES FROM ECOLOGY GUIDANCE

EXECUTIVE SUMMARY

This paper describes how and why certain statistical methods used to support 100 Area cleanup verification packages (CVPs) differ from methods presented in *Statistical Guidance for Ecology Site Managers* (Ecology 1993). The purpose of the paper is to facilitate a broad understanding that these differences exist and agreement that the methods currently employed are appropriate for the unique circumstances of 100 Area cleanup. The overall objective is to anticipate upcoming *Model Toxics Control Act* (MTCA) revisions, which may include the "writing into law" of the MTCA guidance document. Such an outcome will require increased rigor in documenting methods that do not follow the guidance "to the letter."

The MTCA cleanup regulations promulgated at *Washington Administrative Code* (WAC) 173-340 establish criteria that must be met to demonstrate compliance with remedial action goals. The following three criteria must be satisfied with regards to contaminants of concern:

- No single sample concentration is greater than two times the cleanup standard.
- Less than 10% of the sample concentrations exceed the cleanup standard.
- The 95% upper confidence limit (UCL) on the arithmetic mean from verification samples is less than the cleanup standard.

The first and second criteria are designed to reduce the likelihood that localized hot spots will be left behind. The third criterion provides a high level of confidence that, on average, the residual concentrations will be below the cleanup standard.

The Washington State Department of Ecology (Ecology) issued the statistical guidance to help clarify the routine statistical procedures that should be used to assess compliance with the cleanup criteria. For "non-routine" applications, MTCA permits deviations from the guidance, provided the deviations are technically justified. In comparing the statistical methods used for the 100 Area CVPs with the methodology presented in the MTCA statistical guidance, there are two areas of departure:

- Use of composite samples to demonstrate compliance with cleanup standards
- Default sample distribution assumption and calculated UCL using Land's method for evaluating small data sets (fewer than 10 sample results).

USE OF COMPOSITE SAMPLES

Ecology guidance states that composite samples should not be used for final cleanup verification. The potential difficulty with use of composite samples is that the dilution effect could mask the presence of hot spots. In order to assess whether dilution via composite sampling presents a significant concern, it is necessary to consider the 100 Area site cleanup verification process in more detail.

The 100 Area Remedial Action (RA) Project's cleanup verification process provides a progressively more stringent testing for completion of the cleanup of a contaminated soil waste site. This graded approach was selected to balance requirements for waste minimization and for compliance with the MTCA soil cleanup standards. The process involves the following steps:

The 100 Area RA project cleanup verification process is a 3-step process using field screening, variance "hot spot" sampling, and verification compliance sampling.

1. Field screening is used to guide the removal of contaminated soil and to identify when the cleanup goals have likely been achieved.
2. Statistical variance samples are collected to verify compliance with the MTCA "hot spot" criteria. The demonstrated absence of hot spots allows the variance analysis to be used to determine how many samples will be sufficient for the final verification sampling.
3. Based on the variance sampling analysis, statistical verification "composite" samples are collected to verify compliance with the cleanup standards for each contaminant. An alternative statistical methodology for small (less than 10) sample sizes is used to make this determination.

The departures from the default MTCA statistical guidance (i.e., composite samples and an alternative statistical method) are consistent with the requirements of the Ecology guidance and has been accepted by Ecology and the U.S. Environmental Protection Agency (EPA) for the 100 Area RA projects.

A further consideration in determining when it is appropriate to use composite samples relates to the size of an area that constitutes a hot spot. The draft EPA *Geostatistical Sampling and Evaluation Guidance for Soils and Solid Media* (EPA 1996) provides information to indicate the size of the areas sampled for the 100 Area remediations fall well within reasonable size limitations for a hot spot in a residential setting. The Ecology statistical guidance acknowledges that "compositing has been used successfully to evaluate the risk associated with an 'exposure unit,' the area over which people are expected to be exposed at a site and where cleanup actions are being considered. In this case, the average concentration of contaminants over an exposure unit is a meaningful basis for assessing risk and, thus, compositing is a useful sampling technique." Because 100 Area remedial action goals are based on a rural-residential exposure scenario, the EPA guidance is applicable to establishing exposure units for the 100 Areas.

LOGNORMAL DISTRIBUTION ASSUMPTION AND THE USE OF LAND'S METHOD

Per MTCA statistical guidance, the default assumption is that data are lognormally distributed. Unless distribution testing demonstrates this assumption to be in error, the MTCA guidance calls for data evaluation using Land's method. If the default lognormal assumption is rejected, MTCA guidance calls for statistical evaluation based on a normal distribution. Finally, if statistical evaluation shows that both the lognormal and normal distributions should be rejected, MTCA allows for use of a nonparametric (Gilbert's) statistical method, which is applicable to *any* distribution.

An EPA publication entitled *The Lognormal Distribution in Environmental Applications* (EPA 1997) evaluated use of the H-statistic (used in Land's method) against various other statistical methods. The conclusion by EPA is that the H-statistic should not be used to calculate the UCL *even for lognormally distributed data*, especially if the number of samples is less than 30.

To determine how the theoretical evaluation compares with site data, an analysis was conducted using sample results from site remediation closeout activities. The results demonstrate that for small data sets, Land's method (lognormal distribution) diverges strongly from results using either the t-statistic (normal distribution) or the z-statistic (nonparametric) methods. As data set size increases, the results from the three methods tend to converge. Unlike Land's method, the t-statistic and z-statistic methods yield results at smaller data set sizes that are consistent with results obtained for larger data sets.

Based on these considerations, the current approach for 100 Area cleanup verification, is a balance between the extreme approach recommended in the EPA publication (i.e., do not use Land's method at all) and that presented in MTCA guidance. This approach is as follows:

- For data sets with 10 samples or greater, follow the MTCA guidance
- For data sets with less than 10 samples, use the nonparametric (Gilbert's) method to calculate the 95% UCL.

100 AREAS CLEANUP VERIFICATION METHODOLOGY: DEPARTURES FROM ECOLOGY GUIDANCE

BACKGROUND AND PURPOSE

This paper describes how and why certain statistical methods used to support 100 Area cleanup verification packages differ from methods presented in *Statistical Guidance for Ecology Site Managers* (Ecology 1993). The objective of the paper is to facilitate a broad understanding of the differences that exist and support an agreement that the methods currently employed are appropriate for the unique circumstances of 100 Area cleanup.

Cleanup verification packages (CVPs) are used to document completion of remedial actions for specific Hanford Site waste sites. The CVPs present results of statistical evaluations of sampling data documenting that cleanup standards established in a decision document (e.g., a Record of Decision) have been attained. The statistical evaluation used in the CVPs is consistent with the *100 Area Remedial Action Sampling and Analysis Plan* (SAP) (DOE-RL 1998a). Revisions are currently underway to the *Remedial Design Report/Remedial Action Work Plan for the 100 Area* (DOE-RL 1998b) that would clarify many of the details used in the statistical evaluation.

The *Model Toxics Control Act* (MTCA) cleanup regulations promulgated at *Washington Administrative Code* (WAC) 173-340 establish criteria that must be met to demonstrate compliance with remedial action goals. The following three criteria must be satisfied with regards to contaminants of concern (COCs):

- No single sample concentration is greater than two times the cleanup standard.
- Less than 10% of the sample concentrations exceed the cleanup standard.
- The 95% upper confidence limit (UCL) on the arithmetic mean from verification samples is less than the cleanup standard.

The Washington State Department of Ecology (Ecology) issued the *Statistical Guidance for Ecology Site Managers* (Ecology 1993) to help clarify the routine statistical procedures that should be used to assess compliance with the cleanup criteria. Recent proposed changes to WAC 173-340 would incorporate certain elements of the statistical guidance into the MTCA regulations.

The current MTCA statistical guidance (and proposed regulations) provide fairly specific information regarding application of routine statistical methods. However, the regulations allow for use of alternative statistical methods when approved by Ecology. In comparing the statistical methods used within the CVPs developed to date with the methodology presented in the MTCA statistical guidance, two areas of departure were noted.

One departure from MTCA guidance pertains to use of composite samples. Based on MTCA guidance, composite samples are generally not considered appropriate to demonstrate compliance with cleanup standards because compositing may tend to dilute hot spots. As a consequence, composite samples arguably tend to negate criteria designed to identify and reject sites with excessive hot spots (e.g., the criteria that no single sample exceeds twice the cleanup standard and less than 10% of sample concentrations exceed the cleanup standard). In contrast, composite sampling is routinely done to support the cleanup determinations presented in the CVPs.

Second, the MTCA statistical guidance (and proposed rule revision) states that sampling data should be assumed to be lognormally distributed unless demonstrated otherwise and the 95% UCL calculated using Land's method. In contrast, the approach used in the CVPs for evaluating small data sets (fewer than 10 sample results) has consisted of nonparametric statistical methods (i.e., statistical methods that are not based on a specified distribution such as lognormal) rather than Land's method. For data sets consisting of more than 10 sample results, the default approach presented in the MTCA guidance is used.

The purpose of this document is to discuss these departures from the default MTCA positions and provide a technical discussion of the basis for the alternative methods employed.

USE OF COMPOSITE SAMPLES

MTCA statistical guidance illustrates the potential dilution effects from compositing of samples with the following example:

> "... suppose the detection limit for a particular contaminant is 1 mg/kg, and the action level is 3 mg/kg. Ten samples are taken and composited into one sample. If one sample has a concentration of 9 mg/kg, and all of the other samples are uncontaminated, the dilution effect of mixing the single contaminated sample with all the clean soil will cause the overall concentration measured in the soil to be below the detection limit of 1 mg/kg, and the soil will be considered clean. However, the local, hot spot concentration of 9 mg/kg is greater than the 3 mg/kg action level, and the site actually should be considered contaminated."

One cleanup criterion established in the MTCA regulations is that no single sample can exceed twice the cleanup standard. As demonstrated by the example above, the dilution effect inherent in composite sampling could mask the ability to determine whether this criterion – aimed at hot spot identification – has been satisfied.

The typical 100 Area cleanup verification process is not, however, composed of a single sampling event conducted only at the end of the cleanup process. In order to assess whether dilution via composite sampling presents a significant concern, it is necessary to consider the site cleanup verification process in more detail. (For additional information, see the *Instruction Guide for Remediation of the 100 Areas Waste Sites* [BHI 1999]). The process involves the following steps, each involving a more rigorous standard for COC identification and detection:

1. Upon initial completion of site excavation, field screening using radiation detectors for gamma-emitting radionuclides is performed. (Note that gamma-emitting radionuclides contribute the majority of radionuclide dose at 100 Area waste sites; also, they are generally a good marker for other types of contamination.) This screening provides a mechanism for identifying gross radionuclide hot spots at reasonably low detection levels.

2. If the surveys show a site to be potentially clean, sampling to determine contaminant variability and distribution is performed for selected COCs. Six samples are collected per shallow zone sampling area (typically 24 samples total for a small site); these "variance samples" are *not* composited. Variance sample results are initially compared to cleanup standards and then used to compute the minimum number of "cleanup verification samples" required to verify site cleanup. If comparison against cleanup standards indicates the site may not pass the MTCA cleanup criteria listed above, then additional excavation may be performed and the newly excavated areas resampled.

3. If the results of the variance sampling indicate that the site meets remedial action goals, then cleanup verification sampling is performed. For a typical small site there are 4 verification samples for the shallow zone, each formed by compositing four individual aliquots (subsamples) collected from each sampling area. These samples are analyzed for all COCs and are used to demonstrate compliance with final remedial action goals.

A unique feature of the 100 Area cleanup therefore, is the presence of gamma-emitting radionuclides and the associated ability to field-screen for hot spots *prior* to cleanup verification sampling. The vast majority of MTCA sites do not have radionuclide COCs; consequently, the MTCA guidance does not presume this capability.

A second consideration in determining when it is appropriate to use composite samples relates to what size of an area constitutes a hot spot. Obviously, sampling of each square inch of a site to demonstrate no exceedance of a cleanup standard is impractical and unnecessary. On the other hand, taking a single sample from a very large site creates the potential of missing a hot spot.

The draft EPA *Geostatistical Sampling and Evaluation Guidance for Soils and Solid Media* (EPA 1996) includes the following discussion:

> "Of course, even within a hot spot, the concentrations will probably not be completely uniform. For this reason, the exact definition of a hot spot should be specified and tied either to (1) the minimum concentration exceeded by all points within the hot spot area or to (2) the average concentration within the hot spot. For compliance purposes, it is also necessary to specify how large the contaminated area must be to qualify as a hot spot. . ."
>
> "Because of these difficulties, a minimum size area (and approximate geometrical shape such as a circle, square, or rectangle) should be specified in advance before searching for hot spots. The choice of minimum area is somewhat arbitrary, but some guidelines can be drawn from previous United States Environmental Protection Agency (USEPA) risk assessment efforts (e.g., Neptune et al. 1990; Barth 1989). *For most situations, the smallest contiguous physical area of regulatory and/or risk assessment concern would be*

half an acre, particularly when the land is to be used for residential purposes . . ." (Emphasis added.)

This discussion provides two points of reference for further consideration. First, hot spots may be defined based on the average concentration of contaminants within the hot spot. Second, as a "rule-of-thumb," a half an acre may be considered a reasonable minimum hot spot size in a residential setting.

As part of the cleanup verification process, a "decision unit" is established for different subsets of the excavation area: the shallow zone, the deep zone, and overburden. The first two decision units will be considered for purposes of this evaluation.

A decision unit is divided into subunits for sampling purposes. The number of subunits depends on the size of the decision unit. Each subunit is then divided into four (shallow zone) or three (deep zone) sampling units. Thus, a minimum of four composite samples are provided for each shallow zone decision unit and a minimum of three composite samples are provided for each deep zone decision unit. The maximum sample area size for a zone decision unit is 1,548 m^2 (16,667 ft^2) (see BHI 1999 for details).

Upon receipt of analytical data, each decision unit is evaluated to demonstrate compliance with cleanup standards. The 95% UCL statistical evaluation is performed over data from the entire decision unit (e.g., the entire shallow zone decision unit) rather than for each subunit within the decision unit. However, when evaluating compliance with the two remaining cleanup criteria (i.e., no single sample in excess of twice the cleanup level, no more than 10% of the sample concentrations above the cleanup level), the results from the composite sample from within each sample area are compared directly to the cleanup levels. Thus, for the "two times the cleanup level" criterion (designed to reject sites with excessive hot spots), demonstration of compliance is based on results of composite samples from each sample area. In effect, the sample area represents the actual decision area for demonstrating compliance with the "2 times" hot spot criterion.

As mentioned previously, draft EPA guidance provides a point of reference of half an acre for the smallest hot spot size of concern in a residential setting. In contrast, the maximum size sample area in the Hanford Site cleanup verification process is approximately three-eighths of an acre. Thus, the maximum unit size used to evaluate attainment of the "2 times" hot spot criterion is smaller than "the smallest contiguous physical area of regulatory and/or risk assessment concern" in a residential setting, based on EPA guidance.

In conclusion, as far as compositing of samples from within the sample areas, it would, of course, be possible to take only a single sample from within the area. However, this approach would increase the risk of missing a more highly contaminated portion of the sample area (in essence, a "subhot spot"). Greater coverage of the sample area is provided by use of composite samples, and is more likely to yield a result representative of the mean contaminant concentration within the area. The Ecology statistical guidance acknowledges that "compositing has been used successfully to evaluate the risk associated with an 'exposure unit,' the area over which people are expected to be exposed at a site and where cleanup actions are being considered. In this case, the average concentration of contaminants over an exposure unit is a meaningful basis for assessing risk, and thus, compositing is a useful sampling technique." As mentioned earlier, EPA has indicated that one strategy for defining a hot spot is to tie it to the average concentration within the area of concern. The compositing of cleanup verification samples within the relatively small sample area is consistent with the Ecology and EPA guidance in this regard.

LOGNORMAL DISTRIBUTION ASSUMPTION AND THE USE OF LAND'S METHOD

Per MTCA statistical guidance, the default assumption is that data are lognormally distributed. Unless distributional testing demonstrates this assumption to be in error, the MTCA guidance calls for data evaluation using Land's method. Although not reflected in current regulation, the lognormal assumption and use of Land's method has recently been proposed for inclusion into WAC 173-340. Thus, MTCA implementation strongly favors use of Land's method along with a lognormal distribution assumption.

If the default lognormal assumption is rejected based on statistical testing, MTCA guidance calls for statistical evaluation based on a normal distribution. Finally, if statistical evaluation shows that the normal distribution should be rejected, MTCA allows for use of nonparametric statistical methods.

MTCA guidance acknowledges two potential problems with the use of small data sets (defined in the guidance as less than 20 samples):

- It may not be possible to reject either the normal or lognormal distribution; i.e., the data "passes" for both distributions.

- It may be that both the normal and lognormal distributions are rejected; i.e., the data "fails" for both distributions.

In the former situation, the guidance recommends that the data be evaluated assuming a lognormal distribution, or obtain additional samples. In the latter instance, the guidance recommends using an approximation to the UCL that is appropriate for any distribution (referred to as Gilbert's method), or obtain additional samples.

Although the lognormal/Land's method approach is established within MTCA, evaluation of this approach demonstrates the likelihood of error for small data sets. Appendix A presents a discussion of the issue based on a hypothetical data set of known distribution. In comparing Land's method with normal (t-statistic) or nonparametric (z-statistic) tests, it was shown that results from Land's method tend to converge with both the other tests as data set size increases; but for small data sets, Land's method provides an unrealistically large estimate of the 95% UCL. In contrast, the t-statistic and z-statistic methods yield relatively consistent results, both between the two methods and between small and larger data sets.

To evaluate how the theoretical evaluation compares with "real world" data, an evaluation was conducted using sample results from actual 100 Area remediation activities. The data used for this evaluation are described in Appendix B. The results, also shown in Appendix A, reflect the same pattern derived using theoretical data: for small data sets, Land's method diverges strongly from results using either the t-statistic or the z-statistic methods. As data set size increases, the results from the three methods tend to converge. Unlike Land's method, the t-statistic and z-statistic methods yield results at smaller data set sizes that are reasonably consistent with results obtained for larger data sets.

Encountering difficulties with the use of a Land's method is not a situation unique to the 100 Area cleanup effort. An EPA publication entitled *The Lognormal Distribution in Environmental Applications* (EPA 1997) evaluated use of the H-statistic (used in Land's method) against various other statistical methods. EPA concluded that use of the H-statistic in environmental applications may be questionable, especially for small data sets (defined in the publication as less than 30 samples). The paper concludes that the H-statistic should not be used to calculate the UCL *even for lognormally distributed data*, especially if the number of samples is less than 30.

In conclusion, an appropriate balance between the extreme approach to the non-use of Land's method recommended in the EPA publication (do not use it, even for lognormal data, for data sets less than 30) and the MTCA approach (use Land's method regardless of the size of the data set if the set passes the test for lognormality) was reached. It was noted that, based on the simulation study using a known lognormal distribution backed up by the results of the analysis of actual verification sample COC concentrations (Appendix A), the behavior of the 95% UCL based on Land's method becomes much less erratic at population size of 10 or greater. Therefore, a technically sound and justifiable data analysis method is as follows:

- For data sets smaller than 10, the test for distribution is not done and the nonparametric Gilbert's method (applicable for any distribution) is automatically used to calculate the 95% UCL.

- For data sets of 10 of greater, the MTCA guidance is followed.

This approach successfully addresses two concerns:

1. Dealing with unrealistically large 95% UCLs for small sample sizes when the test for distribution indicates the lognormal (a "contamination problem" caused by the statistical analysis)

2. Providing a stable estimate of the 95% UCL when the distribution appears to be neither lognormal nor normal for small sample sizes.

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APPENDIX A

A STUDY OF THE EFFECT ON 95% UCL OF UNDERLYING DISTRIBUTIONAL ASSUMPTION AS A FUNCTION OF SAMPLE SIZE

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A STUDY OF THE EFFECT ON 95% UCL OF UNDERLYING DISTRIBUTIONAL ASSUMPTION AS A FUNCTION OF SAMPLE SIZE

INTRODUCTION

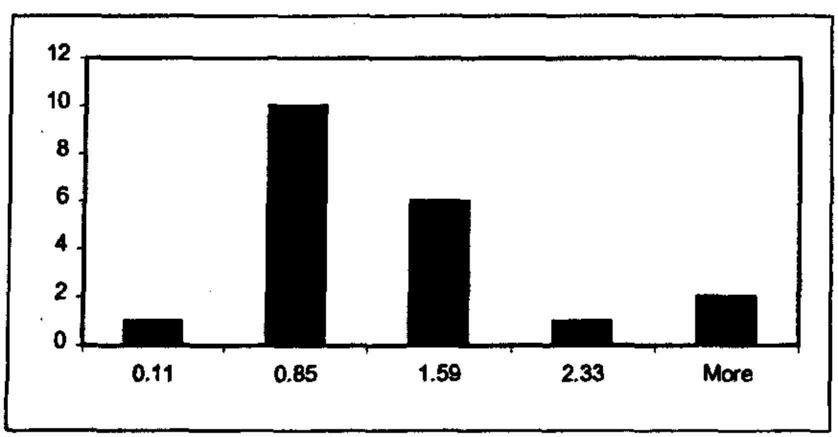
Model Toxics Control Act (MTCA) methodology (Ecology 1993) recommends that all data sets be tested for underlying distribution regardless of sample size and the 95% upper confidence limit (UCL) calculated accordingly. However, there are problems associated with calculating the 95% UCL for some distributions for small sample sizes. This study was undertaken to investigate the effects of sample size on the calculation of the 95% UCL.

Many of the cleanup verification data sets are small; many have less than 10 observations. This is a result of the sampling plans established through the remedial design report and sampling and analysis plan process and has been agreed to by the regulators as part of the CERCLA process. This study looks at the results when the underlying distribution is tested for data sets of various sizes, including those with 10 or fewer observations.

METHODOLOGY

Microsoft Excel™ was used to randomly generate lognormal data sets containing 4, 6, 10, and 20 observations. To more precisely show the effects of sample size, the same seed (125) was used to generate all the data sets. Therefore, the smaller data sets are contained within the larger data sets. These data sets were generated assuming a normal distribution with mean 0 and standard deviation 1. The values were exponentiated to transform the distribution to a lognormal.
A histogram of the 20-sample data set is shown in Figure A-1.

Figure A-1. 20-Sample Data set Frequency.



™ Microsoft Corporation, Redmond, Washington.

Appendix A – A Study of the Effect on UCL on Underlying Distributional Assumption as a Function of Sample Size

Four different methods of calculating the 95% UCL were used to evaluate the performance of the methods for small data sets. The MTCA methodology default assumption is of lognormality (Ecology 1993, Section 2.1.4.2). The method for the 95% UCL for lognormally distributed data is Land's method (Ecology 1993, Section 5.2.1.2). If the data set fails the test for lognormality, then it is tested for normality. The method for the 95% UCL for normally distributed data is based on the Student's t distribution and is found in Section 5.2.1.1 of *Statistical Guidance for Ecology Site Managers* (Ecology 1993). When both lognormality and normality are rejected by statistical tests, the method in Section 5.2.1.3 of the statistical guidance can be applied. This method is based on the standard normal distribution and uses the z-statistic. It is referred to in the cleanup verification process as Gilbert's method.

For a reference point, the 50% upper tolerance limit (UTL) is included. It is a conservative reference and is used only when the cleanup limit is based on acute exposure; therefore, it does not apply to the 100 Area soil site closeout calculations. The 50% UTL methodology is given in Section 5.2.2.3 of the statistical guidance.

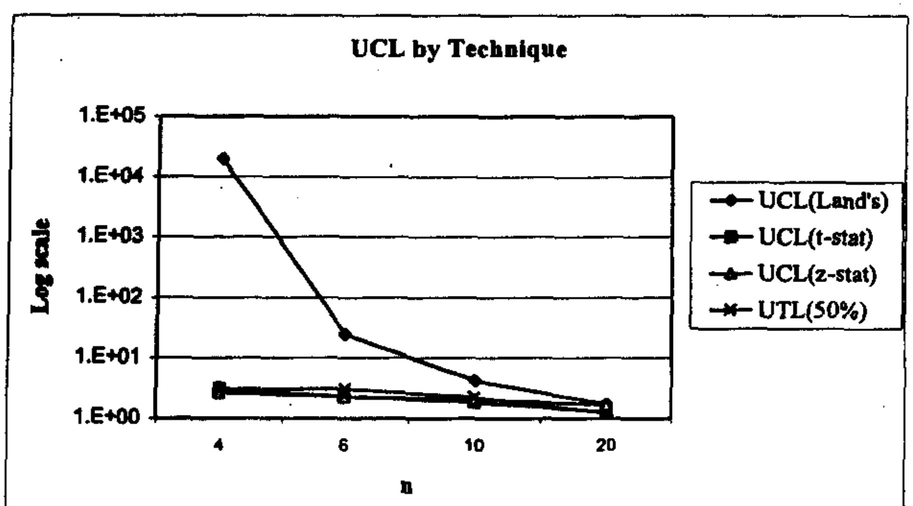
RESULTS

The results of this simulation are shown in Table A-1 and Figure A-2.

Table A-1. UCL by Method and Sample Size.

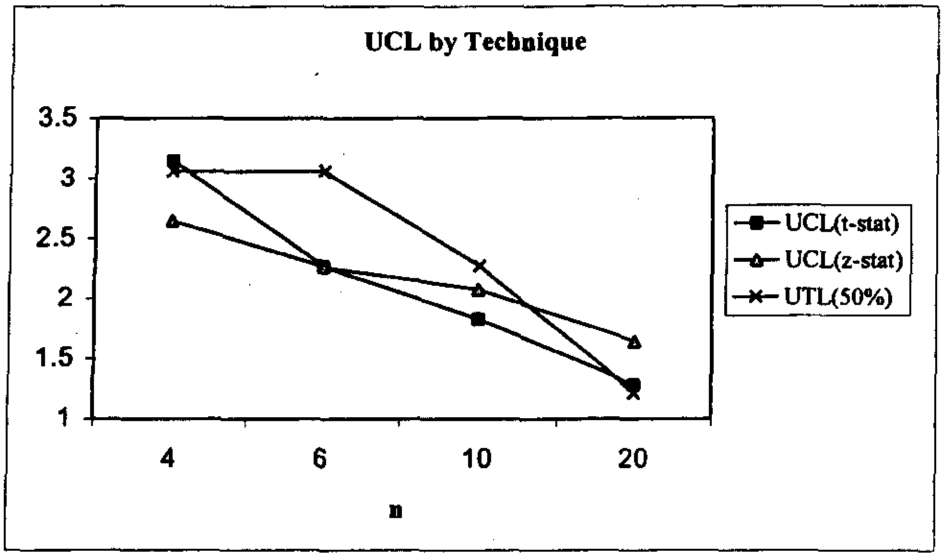
n=	4	6	10	20
UCL(Land's)	19860.75	24.52	4.21	1.75
UCL(t-stat)	3.15	2.27	1.83	1.28
UCL(z-stat)	2.648537	2.265935	2.0748	1.64082
UTL(50%)	3.0649294	3.064929	2.2757	1.20978

Figure A-2. Plot of 95% UCL Using Four Methods for Four Sample Sizes.



A second figure, Figure A-3, is included to show the performance of three of the methods for calculating the UCL. Land's method is excluded so that the remaining three methods can be seen more clearly.

Figure A-3. Plot of 95% UCL Using Three Methods for Four Sample Sizes.



ADDITIONAL DATA EVALUATION WITH ACTUAL CVP COC CONFIRMATION DATA

The analyses reported above were for a randomly generated set of data from the lognormal distribution. A question may be raised about whether the same behavior seen for Land's method for small sample sizes for the generated data would also be seen when applied to real data from the waste site cleanup verification process. The data used for this additional evaluation are described in detail in Appendix B.

The methodology that was used for the analysis of the randomly generated lognormal data was applied to the CVP contaminant of concern (COC) data. Data sets of 4, 6, 10, and 20 samples were drawn from the concentration data (each a composite of 4 samples) for a specific COC from a compliance data set (overburden, shallow zone, deep zone). In the same manner as for the lognormally generated data, the smaller data sets are contained within the larger data sets. Because the distribution of the data is unknown, the test for distribution was done for each data set, using the lognormal, followed by the normal. If the data set met the test for the lognormal distribution, it was not tested for the normal distribution.

The particular COC and the compliance set were chosen to evaluate the effect of the different 95% UCL calculation methods on common data conditions observed in the CVP data. The data conditions are as follows, with the data set chosen to illustrate their effects:

- A radionuclide with large numbers of nondetects, for which all concentrations are well below the remedial action goal (RAG) - americium-241 in the overburden with 84% nondetects.

- A radionuclide with high dose consequences - cesium-137 in the overburden with 23% nondetects.

- A COC for which the RAG is set at background and there are no nondetects - uranium-238 with 0% nondetects in the overburden.

- A COC for which the mean is close to the RAG and there are small numbers of nondetects - lead in the deep zone with 1.3% nondetects, a mean of 9.3 ppm and a RAG of 10.2 ppm.

The results are given in Table A-2. There are two subtables for each COC. The table on the left gives the selected distribution for the data set and the 95% UCL appropriate for the distribution. The table on the right shows the 95% UCL calculated according to Land's method, the t-statistic, the z-statistic (Gilbert's method), and the 50% UTL for each of the four sample sizes.

Table A-2. UCL by Method and Sample Size for Actual CVP COC Concentration Data.

Number *Samples*	MTCA *Distribution*	UCL	n	4	6	10	20
Overburden Am-241, 84% ND, all values well below RAG							
4	Lognormal	3.34	UCL(Land's)	3.34	0.12	0.04	0.03
6	Lognormal	0.12	UCL(t-stat)	0.05	0.04	0.03	0.02
10	Lognormal	0.04	UCL(z-stat)	0.04	0.03	0.03	0.02
20	Lognormal	0.03	UTL(50%)	0.056	0.056	0.024	0.0171
Overburden Cs-137, high dose consequence, 23% ND							
4	Lognormal	9274714401.13	UCL(Land's)	9.3E+09	301.33	4	0.38
6	Normal	0.15	UCL(t-stat)	0.19	0.15	0.15	0.11
10	Normal	0.15	UCL(z-stat)	0.16	0.14	0.15	0.11
20	Neither	0.11	UTL(50%)	0.206	0.206	0.206	0.09
Overburden U-238, 0% ND, RAG=background							
4	Lognormal	0.78	UCL(Land's)	0.78	0.79	0.77	0.70
6	Lognormal	0.79	UCL(t-stat)	0.77	0.79	0.76	0.7
10	Lognormal	0.77	UCL(z-stat)	0.75	0.78	0.76	0.70
20	Lognormal	0.70	UTL(50%)	0.763	0.798	0.794	0.701
Deep Pb, Mean close to RAG, small ND%							
4	Lognormal	37.6	UCL(Land's)	37.6	12.21	10.76	11.91
6	Lognormal	12.21	UCL(t-stat)	12.09	9.36	8.75	12.57
10	Lognormal	10.76	UCL(z-stat)	10.65	8.86	8.56	12.37
20	Lognormal	11.91	UTL(50%)	11.9	11.9	9.4	8

The behavior of the different UCL methods for the different sample sizes observed for the lognormal distribution was duplicated for the CVP COC data. That is, Land's method produced unrealistically large 95% UCLs for four and six sample data sets (with one exception: uranium-238) and then produced more reasonable estimates of the UCL for 10- and 20-sample data sets. The 95% UCLs calculated using the t-statistic and the z-statistic produced consistent results regardless of the size of the sample.

CONCLUSIONS

Specifically, calculating the 95% UCL for lognormally distributed data using Land's method for small (n<=20) data sets can lead to unrealistically high 95% UCL values. In the methodology used in the cleanup verification process for the 100 Area Remedial Action sites, the underlying distribution is tested only for those data sets with at least 10 observations. For those data sets with fewer than 10 samples, the UCL will be based on Gilbert's method, the nonparametric method described in Sections 5.2.1.3 and 5.2.1.4 of the statistical guidance.

REFERENCE

Ecology, 1993, *Statistical Guidance for Ecology Site Managers*, Ecology Publication 92-64, Supplement S-6, "Analyzing Site or Background Data with Below-Detection Limit or Below PQL Values (Censored Data Sets)," Washington State Department of Ecology, Olympia, Washington.

APPENDIX B

SUMMARY OF DATA ANALYSIS OF THE 100 AREA CVP CONFIRMATION DATA

APPENDIX B

SUMMARY OF DATA ANALYSIS OF THE 100 AREA CVP CONFIRMATION DATA

PURPOSE

As an exercise in continuous improvement, the CVP confirmation data were analyzed to provide information back to the project on the statistical performance of the closeout process by evaluating the variances, statistical distribution types, and sample size determinations for the individual COCs.

DATA

The data sets used for this analysis consist of deep zone, shallow zone, and overburden closeout verification data for 13 sites for which the CVP process had been completed as of September 1999. The data for all sites were combined into a single data set for each zone. The reasons for combining the data from the different sites are two-fold:

1. A larger data set provides a better opportunity for evaluating the statistical distribution.
2. The residual COC concentrations can legitimately be combined into a single data set for each zone because all sites are cleaned up to the same remedial action goals. The act of cleaning up the sites erases the pre-remediation differences between the sites.

These data include duplicate samples treated as individual values. In practice, these duplicate data are averaged with the corresponding original value for evaluation in the CVP process. However, that was not done for this first cut analysis, because the duplicate data typically result in only one or two additional samples per waste site.

Table B-1 shows the number of samples collected for each contaminant of concern (COC) in each of the three zones for each waste site. The data set sizes vary because only the COCs specific to each site were analyzed. There are 19 COCs that were analyzed for at least once. The COCs uranium-235, barium, and bis(2-ethylhexyl)phthalate were analyzed for only in the *shallow zone at the 1607-D2 septic tank and tile field sites.*

Not all waste sites had confirmation data for each of the three zones. Some waste sites had no overburden that could be considered as potentially clean backfill material. Some of the shallower waste sites without significant percolation of contamination through the vadose zone did not include a deep zone. The overburden data set is made up of 5 sites with 16 COCs. The overburden data sets for the individual COCs are the smallest, ranging from 41 to 55 samples. The shallow zone data set consists of 13 sites with 19 contaminants. The individual shallow zone COC data sets had the most variation in size, ranging between 56 and 89 samples. The deep zone data set is made up of 7 sites with 16 COCs. The individual COC deep zone data sets had between 67 and 80 samples.

Table B-1. CVP Sample Summary by Site and COC.

Site	Am-241	Pu-238	Pu-239/40	Co-60	Cs-137	U-235	U-238	Eu-152	Eu-154	Eu-155	Ni-63	Strontium	Cr+6	Hg	Ba	Cr (Total)	Lead	Bis2eph*	Ar1260
Overburden																			
107-D5	5	5	5	5	5	0	0	5	5	5	0	5	5	0	0	0	0	0	5
116-D-7	9	9	9	9	9	0	0	9	9	9	9	9	9	9	0	9	9	0	0
116-B-1	11	11	11	11	11	0	11	11	11	11	11	11	11	11	0	11	11	0	0
116-C-1	17	11	12	13	16	0	17	14	11	17	10	17	17	17	0	17	17	0	0
116-C-5	13	13	13	13	13	0	13	13	13	13	13	13	13	13	0	13	13	0	0
Total	**55**	**49**	**50**	**51**	**54**	**0**	**41**	**52**	**49**	**55**	**43**	**55**	**55**	**50**	**0**	**50**	**50**	**0**	**5**
Shallow Zone																			
107-D1	5	5	5	5	5	0	0	5	5	5	0	5	5	0	0	0	5	0	5
107-D2	5	5	5	5	5	0	0	5	5	5	0	5	5	0	0	0	0	0	5
107-D5	5	5	5	5	5	0	0	5	5	5	0	5	5	0	0	0	0	0	5
116-D-7	9	9	9	9	8	0	0	9	9	9	9	9	9	9	0	9	9	0	0
116-DR-9	0	9	9	9	9	0	0	9	9	9	9	9	9	0	0	9	9	0	9
1607-D2 STank	0	0	0	0	0	0	5	5	0	0	0	0	5	5	5	5	5	5	5
1607-D2 TField	0	0	0	0	0	5	5	5	0	0	0	0	5	5	0	0	5	5	5
116-B-1	9	9	9	1	6	0	9	7	1	0	9	9	9	9	0	9	9	0	0
116-B-11	9	9	9	9	9	0	9	9	9	9	9	9	9	9	0	9	9	0	0
116-B-13	5	5	5	5	5	0	5	5	5	5	0	5	5	5	0	5	5	0	0
116-B-14	5	5	5	5	5	0	5	5	5	5	0	5	5	5	0	5	5	0	0
116-C-1	9	9	9	9	9	0	9	9	9	9	9	9	9	9	0	9	9	0	0
116-C-5	9	9	9	9	9	0	9	9	9	9	9	9	9	9	0	9	9	0	0
Total	**70**	**79**	**79**	**71**	**75**	**5**	**56**	**87**	**71**	**70**	**54**	**79**	**89**	**65**	**5**	**69**	**79**	**10**	**34**
Deep Zone																			
116-D-7	10	10	10	10	10	0	0	10	10	10	10	10	10	10	0	10	10	0	0
116-DR-9	0	13	13	13	13	0	0	13	13	13	13	13	13	0	0	13	13	0	13
116-B-1	7	7	7	7	7	0	7	7	7	7	7	7	7	7	0	7	7	0	0
116-B-11	13	13	13	13	13	0	13	13	13	13	13	13	13	13	0	13	13	0	0
116-B-14	4	4	4	4	4	0	4	4	4	4	0	4	4	4	0	4	4	0	0
116-C-1	10	10	10	10	10	0	10	10	10	10	9	10	10	10	0	10	10	0	0
116-C-5	23	23	23	23	23	0	23	23	23	23	23	23	23	23	0	23	23	0	0
Total	**67**	**80**	**80**	**80**	**80**	**0**	**57**	**80**	**80**	**80**	**75**	**80**	**80**	**#**	**0**	**80**	**80**	**0**	**13**

STATISTICAL ANALYSIS METHODOLOGY

This analysis of the CVP data followed the CVP statistical analysis methodology with a few exceptions. In the CVP methodology, data replacement is done in two cases. For the radionuclides, all nondetect data are replaced with the associated minimal detected activity (MDA). For nonradionuclides, nondetect data are replaced with one-half the detection limit. For this analysis, nonradionuclide data replacement followed the CVP methodology. To lessen the bias imposed upon the data, MDA replacement was done for radioactive COCs only for negative reported values, not for all nondetect data. The MDA replacement was required for the negative reported values in order to log transform the data prior to testing for the lognormal distribution.

Summary statistics were computed for each COC data set for each zone (see Tables B-2 through B-4). The values reported were the number of data values, the mean, the standard deviation, the minimum and maximum values, the percent of the samples in which the contaminant was undetected, and the maximum value that was qualified with a "U" (nondetect). Each data set was analyzed using MTCAStat to determine the recommended distributional assumption. MTCAStat tests first for the lognormal distribution. If the test for lognormality fails, then the normal distribution is tested. The 95% upper confidence limit (UCL) was calculated using the CVP methodology according to distribution type. If the data set failed the test for both distribution, the distributional type is listed as "neither." For several of the nonradionuclide COCs, the distributional type is listed as "maximum." That reflects the fact that the number of nondetects is greater that 50% of the samples and Supplement S-6 to the MTCA *Statistical Guidance for Ecology Site Managers* (Ecology 1993) permits the use of the largest value in the data set as the UCL. According to the CVP methodology, the maximum value is not used as the 95% UCL for radionuclide data. Therefore, in some cases (plutonium-238 in the overburden), the test for statistical distribution is carried out on a data set of 100% nondetect values.

For each COC data set, the required number of samples (n) was calculated using the CVP formula,

$$n = s^2 * (z_{1-\alpha}+z_{1-\beta})^2/(RAG-\mu)^2 + 0.5*z_{1-\alpha}^2$$

where:

s	= the sample standard deviation
$z_{1-\alpha}/z_{1-\beta}$	= the values of the standard normal distribution corresponding to 1 minus the Type I and Type II error rates, respectively, of the statistical test (usually 0.05 and 0.20)
RAG	= the cleanup value
μ	= estimated by the sample mean.

This sample size calculation is based on a normal distribution and is the one used in the *100 Area Remedial Action Sampling and Analysis Plan* (DOE-RL 1998a) (with the addition of the last term, which is a correction for the fact that the variance of the population is unknown).

Table B-2. Deep Zone Summary.

Contaminant	Unit	RDR Background	RDR RAG	n	Mean	Stdev	Min*	Max	Percent ND	Max ND*	MTCAStat Distribution	MTCAStat Replace <=0 95% UCL	n_d	N
Am-241	pCi/g	NA	1577000	67	1.92	6.61	0.007	52.4	14.9%	0.051	Lognormal	4.97	2	2
Pu-238	pCi/g	0.004	1123	80	0.14	0.41	0.003	3.31	53.8%	0.086	Lognormal	0.17	2	2
Pu-239/40	pCi/g	0.025	718600	80	4.03	11.83	0.00574	89.9	6.3%	0.063	Lognormal	8.72	2	2
Co-60	pCi/g	0.008	NA	80	8.41	15.20	0.00519	94.4	5.0%	0.0272	Lognormal	42.52	NA	NA
Cs-137	pCi/g	1.1	NA	80	54.88	213.47	0.0364	1900	0.0%	NA	Neither	94.14	NA	NA
U-238	pCi/g	1.1	1.1	57	0.92	0.32	0.0989	2.8	0.0%	NA	Neither	0.99	20	NA
Eu-152	pCi/g	NA	NA	80	66.06	124.71	0.203	844	0.0%	NA	Lognormal	160.95	NA	NA
Eu-154	pCi/g	0.033	NA	80	9.05	16.36	0.00149	104	7.5%	0.265	Lognormal	37.07	NA	NA
Eu-155	pCi/g	0.054	NA	79	0.47	0.69	0.00875	3.49	59.5%	0.529	Lognormal	0.75	NA	NA
Ni-63	pCi/g	NA	NA	75	408.19	860.92	0.259	6140	13.3%	8.42	Lognormal	1478.36	NA	NA
Strontium	pCi/g	0.18	NA	80	3.86	15.11	0.122	135	3.8%	0.934	Neither	6.64	NA	NA
Cr+6	mg/kg	18.5	2.2	79	0.67	0.93	0.015	4.4	24.1%	0.4	Lognormal	2.03	2	36
Hg	mg/kg	0.33	0.33	67	0.91	2.02	0.009	14.5	4.5%	0.01	Lognormal	2.28	2	30
Cr (total)	mg/kg	18.5	36	80	66.44	82.44	6.8	449	0.0%	NA	Lognormal	84.07	47	64
Lead	mg/kg	10.2	10.2	80	9.30	8.41	2.2	49.2	1.3%	2.25	Lognormal	10.84	537	1638
PCB	ug/kg	NA	500	13	84.58	63.35	17.5	180	30.8%	18	Neither	113.49	2	NA

*MDA for radionuclide values <=0, 1/2DL for nonradionuclide nondetects.

Lognormal	12
Normal	0
Neither	4
Maximum	0
Total	16

Table B-3. Overburden Summary.

Contaminant	Unit	RDR Background	RDR RAG	n	Mean	Stdev	Min*	Max	Percent ND	Max ND*	MTCAStat Distribution	MTCAStat Replace <=0 95% UCL	n_d	N
Am-241	pCi/g	NA	31.1	53	0.02	0.02	0.0033	0.15	83.0%	0.15	Lognormal	0.03	2	5
Pu-238	pCi/g	0.004	37.4	55	0.02	0.02	0.001	0.0672	100.0%	0.0672	Lognormal	0.03	2	2
Pu-239/40	pCi/g	0.025	33.9	55	0.03	0.02	0.002	0.152	70.9%	0.0482	Lognormal	0.04	2	5
Co-60	pCi/g	0.008	1.4	55	0.04	0.05	0.00097	0.265	78.2%	0.0472	Lognormal	0.06	2	6
Cs-137	pCi/g	1.1	6.2	55	0.13	0.14	0.00083	0.722	23.6%	0.071	Lognormal	0.25	2	6
U-238	pCi/g	1.1	1.1	41	0.69	0.11	0.46	0.918	0.0%	NA	Lognormal	0.72	2	7
Eu-152	pCi/g	NA	3.3	55	0.31	0.45	0.016	2.5	61.8%	0.288	Lognormal	0.48	2	8
Eu-154	pCi/g	0.033	3	55	0.06	0.06	0.0066	0.392	100.0%	0.392	Neither	0.07	2	NA
Eu-155	pCi/g	0.054	125	55	0.04	0.02	0.00	0.08	100.0%	0.08	Normal	0.05	2	NA
Ni-63	pCi/g	NA	4026	50	5.07	3.59	0.11	14.2	98.0%	14.2	Neither	5.91	2	NA
Strontium	pCi/g	0.18	4.5	55	0.15	0.13	0.0115	0.564	58.2%	0.15	Lognormal	0.2	2	5
Cr+6	mg/kg	18.5	2.2	55	0.10	0.15	0.02	0.41	78.2%	0.41	Maximum	0.41	2	NA
Hg	mg/kg	0.33	24	50	0.01	0.01	0.0085	0.09	86.0%	0.01	Maximum	0.09	2	NA
Cr (total)	mg/kg	18.5	80000	50	11.31	3.97	2.6	17.6	0.0%	NA	Neither	12.23	2	NA
Lead	mg/kg	10.2	353	50	4.37	1.48	2	10.3	0.0%	NA	Lognormal	4.75	2	3
PCB	ug/kg	NA	500	5	16.5	0	16.5	16.5	100.0%	16.5	Maximum	16.5	2	NA

*MDA for radionuclide values <=0, 1/2DL for nonradionuclide nondetects.

Lognormal	9
Normal	1
Neither	3
Maximum	3
Total	18

Table B-4. Shallow Zone Summary.

Contaminant	Unit	RDR Background	RDR RAG	n	Mean	Stdev	Min*	Max	Percent ND	Max ND*	MTCAStat Distribution	MTCAStat Replace <=0 95% UCL	n_d	N
Am-241	pCi/g	NA	31.1	81	0.058	0.094	0.007	0.493	67.9	0.166	Lognormal	0.09	2	3
Pu-238	pCi/g	0.004	37.4	84	0.026	0.041	0.012	0.359	96.4	0.144	Lognormal	0.03	2	5
Pu-239/40	pCi/g	0.025	33.9	84	0.054	0.104	0.011	0.724	69	0.0888	Lognormal	0.06	2	2
Co-60	pCi/g	0.008	1.4	84	0.045	0.065	0.008	0.401	64.3	0.069	Neither	0.06	2	NA
Cs-137	pCi/g	1.1	6.2	84	0.489	1.268	0.007	10	22.6	0.0375	Lognormal	1.16	2	15
U-235	pCi/g	0.11	1	5	0.028	0.012	0.035	0.046	80	0.0407	Lognormal	0.05	2	4
U-238	pCi/g	1.1	1.1	56	0.774	0.33	0.029	1.49	7.1	0.0327	Normal	0.85	8	NA
Eu-152	pCi/g	NA	3.3	94	0.451	0.716	0.022	4.43	37.2	0.19	Lognormal	1.16	2	24
Eu-154	pCi/g	0.033	3	84	0.083	0.09	0.025	0.359	88.1	0.187	Neither	0.10	2	NA
Eu-155	pCi/g	0.054	125	84	0.042	0.021	0.025	0.126	96.4	0.126	Normal	0.05	2	NA
Ni-63	pCi/g	NA	4026	54	3.775	3.58	2.1	22.4	75.9	8.58	Lognormal	5.62	2	5
Sr Total	pCi/g	0.18	4.5	84	0.164	0.205	0.019	4.12	69	4.12	Neither	0.20	2	NA
Cr+6	mg/kg	18.5	2.2	94	0.283	0.427	0.015	1.9	75.5	0.43	Maximum	1.9	2	NA
Hg	mg/kg	0.33	24	65	0.021	0.026	0.001	0.19	61.5	0.19	Maximum	0.19	2	NA
Ba	mg/kg	132	5600	5	54.38	4.043	50.6	60.3	0	NA	Lognormal	58.52	2	2
Cr Total	mg/kg	18.5	80000	65	9.899	5.693	2.5	33.6	0	NA	Lognormal	11.21	2	2
Pb	mg/kg	10.2	353	79	4.078	3.062	0.88	20	8.9	9.2	Lognormal	5.32	2	3
Bis	ug/kg	NA	71400	10	176	9.661	170	200	100	200	Maximum	200	2	NA
PCB	ug/kg	NA	500	39	35.78	100.7	16.5	640	94.9	20	Maximum	640	2	NA

*MDA for radionuclide nondetects, 1/2DL for nonradionuclide nondetects.

Lognorma l	10
Normal	2
Neither	3
Maximum	4
Total	19

Sample size calculations were also made for COCs using MTCAStat methodology for the lognormal where that was the recommended distribution. The MTCAStat formula is an optimization of n calculated with the following formula,

$$n = 1+((s_y * H_{0.95}(s_y,n)) / (LN(0.8*RAG)-\mu_y-0.5*s_y^2))^2$$

where the variables are defined as above, s_y and μ_y are the standard deviation and mean of the *log transformed data, and* $H_{0.95}(s_y,n)$ *is the* H *function used in Land's method described in this* report. Because MTCAStat cannot perform the sample size calculations when the data are far from the target value (80% of the remedial action goal [RAG]), the MTCAStat sample size calculations were done in an Excel™ spreadsheet using H values from Table A12 of Gilbert (1987).

RESULTS

The results for the three zones are given in Tables B-2, B-3, and B-4. Table B-2 is the overburden summary, Table B-3 is the shallow zone summary, and Table B-4 is the deep zone summary.

In the overburden, the percent nondetects ranged from 0% for total chromium, lead, and uranium-238 to 100% for polychlorinated biphenyls (PCBs). The MTCAStat recommended distribution was lognormal for 50% of the contaminants. None of the calculated 95% UCL values were in excess of the RAG for the overburden. The CVP sample size was two (compared to the default number of four for each decision subunit) for all COCs. This reflects the fact that the remedial action project cleans up to levels significantly below the RAGs for most COCs. The sample sizes calculated assuming lognormally distributed data ranged from two to eight.

In the shallow zone, the percent nondetects ranged from 0% for barium and total chromium to 100% for bis(2-ethylhexyl)phthalate. The MTCAStat recommended distribution was lognormal for 50% of the contaminants. The 95% UCL value calculated was in excess of the RAG only for PCBs, where the maximum value was used for the 95% UCL due to the percent nondetects being in excess of 50%. This value (640 µg/kg) is a duplicate value and would be reduced to 329 µg/kg (below the RAG) if it had been averaged with the original sample. The CVP sample size was two for all contaminants except uranium-238, whose sample size was eight. The sample size for those COCs with lognormally distributed data ranged from 2 to 15.

In the deep zone, the percent nondetects ranged from 0% for cesium-137, uranium-238, europium-152, and total chromium to 59.5% for europium-155. The MTCAStat recommended distribution was lognormal for 75% of the COCs. The calculated 95% UCL value was in excess of the RAG for mercury, total chromium, and lead because the RAG is based on the conservative MTCA 100 times rule. In the deep zone, the only pathway for exposure to contamination is through migration of the contaminant through the vadose zone to groundwater. In the case where the deep zone RAG is exceeded, the modeling of contaminant migration is used to

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determine whether the COC will reach the groundwater within 1,000 years at concentrations above the RAG. If this is not the case, then the RAG is considered to have been met. For most of the deep zone metal COCs, the distribution coefficient is large enough to ensure that the contamination would not pose a threat to groundwater. There are no deep zone RAGs for cobalt-60, cesium-137, europium-152, europium-154, europium-155, nickel-63, and total strontium. The cleanup criterion that must be met is the cumulative dose of 4 mrem/yr for the gamma-emitting radionuclides. The CVP sample size ranged from 2 to 537 (lead). Other sample size estimates of note are 20 samples for uranium-238 and 47 samples for total chromium. The sample sizes for those COCs with lognormally distributed data ranged from 2 to 1,638 (lead). Large sample sizes were obtained for chromium+6 (36), mercury (30), and total chromium (64). These larger sample sizes reflect the fact that the RAG is set at background levels and more samples are needed, in theory, to differentiate small differences in concentration.

CONCLUSIONS

Based on the analyses of the 100 Area Remedial Action waste site cleanup confirmation samples, it is clear that one statistical distribution type is not universally applicable for all of the COCs. It is surprising how many times neither the lognormal nor normal distribution is selected, even for the relatively large sample sizes created by pooling the data.

The assumed statistical distribution can have a significant impact on the number of samples needed to demonstrate compliance with the remedial action goals. A review of Tables B-2 through B-4 shows that, for many of the COCs, it is possible to demonstrate compliance with relatively few samples (two to six). That is generally the case because the RAG tends to be large compared to the observed concentrations in the confirmation samples. When the number of samples is larger than two to six, it is usually because the RAG is very close (and in some cases, identical to) the background level for the COC.

The default sample size per decision unit as defined in the 100 Area sampling and analysis plan (DOE-RL 1998a) is four. Larger sites require more samples because they are made up of several decision units.

Several options were evaluated for determining sample sizes for confirmatory sampling for the diverse set of COCs that are likely to be encountered at a 100 Area waste site:

Option 1: Default to the largest sample size for all COCs and present to the regulators. This approach would result in high analytical costs.

Option 2: Collect the number of samples on a COC- and zone-specific basis according to the calculated sample sizes in Tables B-2 through B-4. This approach would produce lower analytical costs than option 1, but field implementability is an issue.

Option 3: Current design of four composite samples per geographic decision unit is reasonable based on Tables B-2 through B-4 and the following observations:

1. **Deep Zone Metals** - The RAGs are based on the conservative 100 times groundwater standard per MTCA. However, if the 100 times test fails, the *Remedial Design Report/Remedial Action Work Plan for the 100 Area* (DOE-RL 1998b) calls for modeling to determine compliance.

2. **Special case of Cr^{+6} in the deep zone** - An analysis of the data collected so far suggests that the cleanup performance with respect to this constituent is acceptable, so there is no need to make an exception.

3. **Uranium-238** - This is a naturally occurring isotope with the remedial action goal set at background. This situation leads to very large sample population sizes. Similar to the discussion for Cr^{+6} in item 2, performance suggests that there is no need to make an exception.

4. **Europium-152 and Cesium-137** - These two isotopes have very short half-lives (13.6 years for europium-152 and 30.2 years for cesium-137) and will decay away in a relatively few years; therefore, making an exception for these isotopes is unwarranted. The 100 Area Record of Decision (ROD) specifically mentions short-lived radionuclides as one element if balancing factors are invoked.

RECOMMENDATION

The majority of the 100 Area sites are small sites (<929 m^2 [<10,000 ft^2]) with lower risks. Therefore, the use of four composite samples at these sites is adequate to demonstrate compliance with the conditions of the ROD. For larger sites, having the number of samples scaled to the size of the site is a sound method for determining the number of compliance samples required to demonstrate compliance with the conditions of the ROD.

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Ecology, 1993, *Statistical Guidance for Ecology Site Managers,* Ecology Publication 92-64, Supplement S-6, "Analyzing Site or Background Data with Below-Detection Limit or Below PQL Values (Censored Data Sets)," Washington State Department of Ecology, Olympia, Washington.

UNDERGROUND RADIOACTIVE WASTE SITES

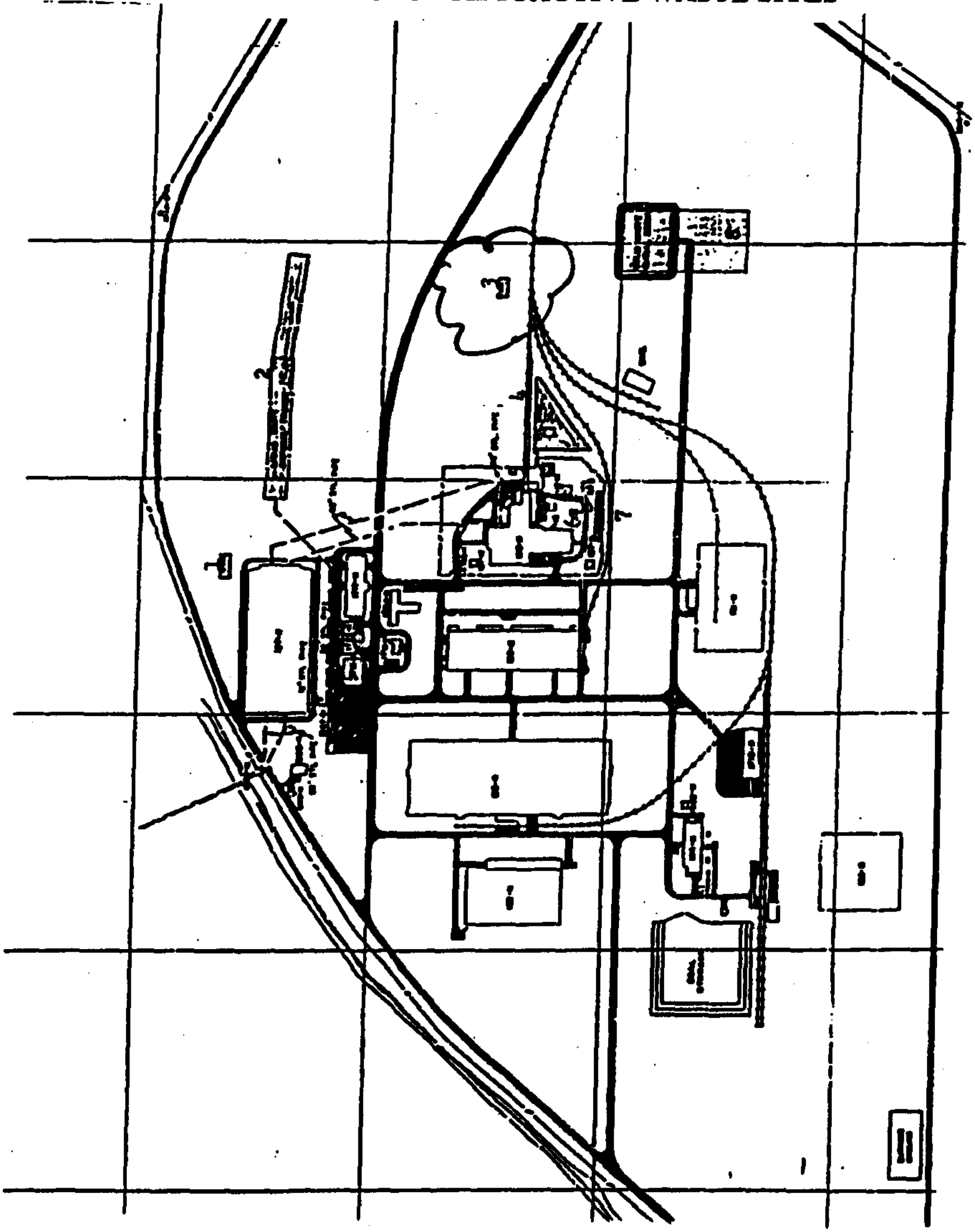
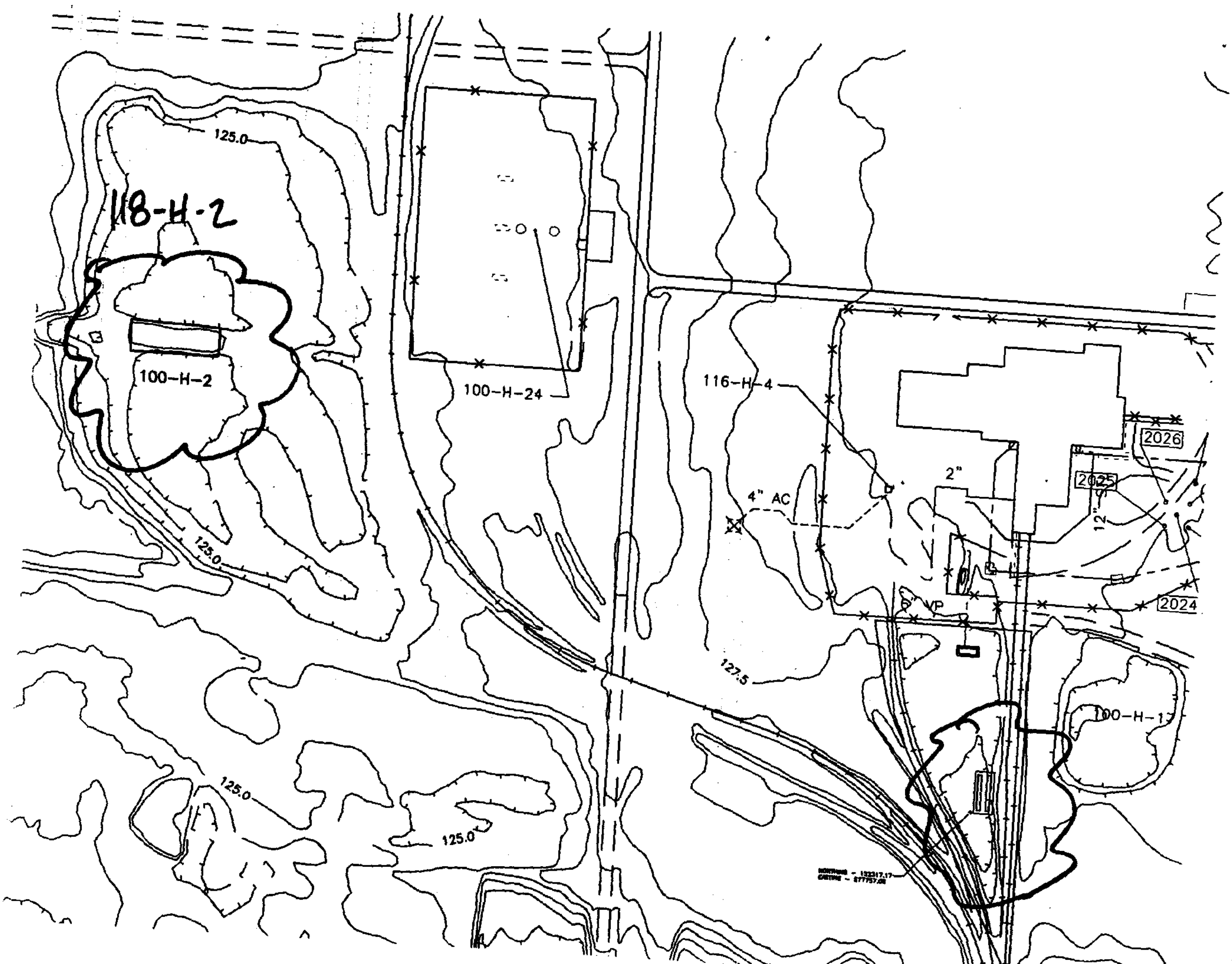
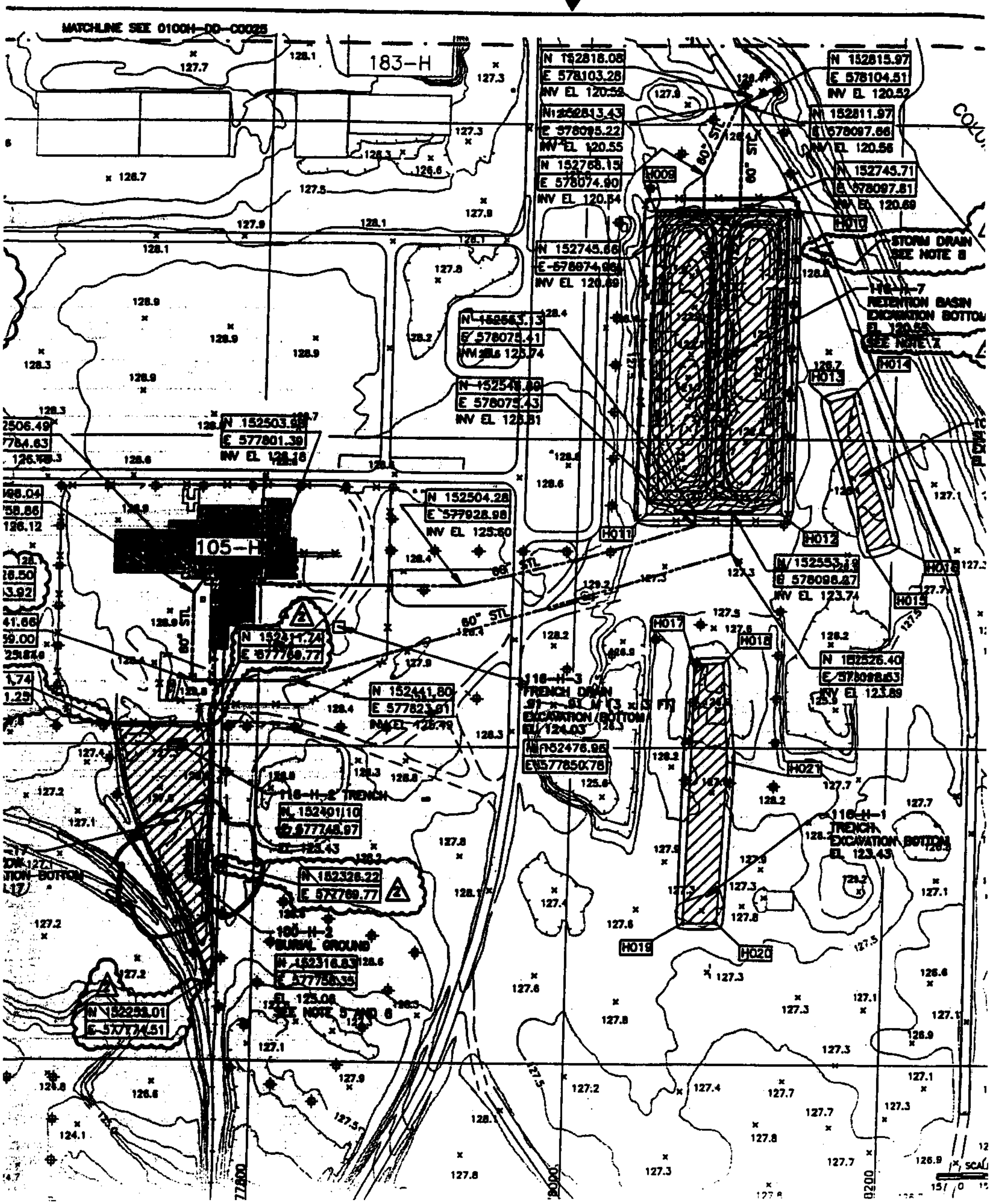


Figure 2. Number 3 marks the location of the buried pipe (Source: HW-46715).


118-H-2
125.0
100-H-2
100-H-24
116-H-4
4" AC
2"
2026
2025
12"
2024
6" VP
127.5
100-H-17
125.0
125.0
125.0

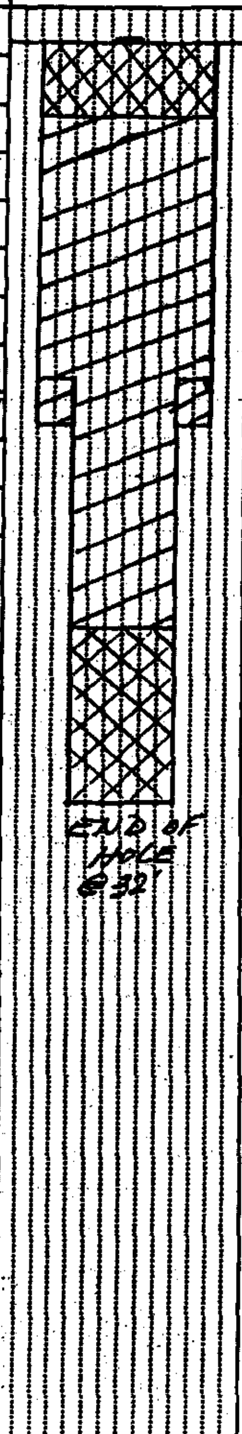
Attachmen


MATCHLINE SEE 0100H-DD-C0025
183-H
105-H
N 152818.08
E 578103.28
INV EL 120.52
N 152815.97
E 578104.51
INV EL 120.52
N 152811.97
E 578097.66
INV EL 120.56
N 152768.15
E 578074.90
INV EL 120.64
N 152745.71
E 578097.81
INV EL 120.69
N 152745.66
E 578074.66
INV EL 120.69
H009
H010
H011
H012
H013
H014
H015
H016
H017
H018
H019
H020
H021
STORM DRAIN
SEE NOTE 8
116-H-7
RETENTION BASIN
EXCAVATION BOTTOM
EL 120.55
SEE NOTE 7
N 152503.98
E 577801.39
INV EL 128.16
N 152504.28
E 577928.98
INV EL 125.60
N 152553.19
E 578098.87
INV EL 123.74
N 152526.40
E 578098.63
INV EL 123.89
N 152441.80
E 577823.01
116-H-3
FRENCH DRAIN
EXCAVATION BOTTOM
EL 124.03
N 152476.96
E 577850.78
116-H-2 TRENCH
N 152401.10
E 577748.97
N 152326.22
E 577769.77
116-H-1
TRENCH
EXCAVATION BOTTOM
EL 123.43
100-H-2
BURIAL GROUND
N 152316.83
E 577756.35
EL 125.06
SEE NOTE 5 AND 6
N 152258.01
E 577774.51
60" STL
77800
78000
78200
SCALE

WELL SUMMARY SHEET

Date: 5/4/00

Well ID: C 3048		Well Name: C 3048	
Location: 116-H-1 Pit, 100-H		Project: 116-H-1 Characterization	
Prepared By: J.M. Faurote	Date: 5/4/00	Reviewed By: DC Weekes	Date: 5/5/00
Signature: JM Faurote		Signature: DC Weekes	

CONSTRUCTION DATA: Description	Diagram	Depth in Feet	Graphic Log	GEOLOGIC/HYDROLOGIC DATA: Lithologic Description
Brass Cap @ Surface Cement from 0-2.9' 3/8" Bentonite Crumbles from 2.9' - 24.5' 3/8" Bentonite Pellets (Hydrated) annular seal from 14' to 15.8' Cement from 24.5 to 32' 0-16' 10 3/4" temp casing 16'-32' 9" temp. casing All Temporary Casing Removed All depths are below ground surface.	 END OF HOLE @ 32'	0 10 20 30		0-18.5 Silty Sandy Gravel Cemented 18.5-TD (32') Sandy Gravel 32' End of hole Water Level @ 26.5' on 5/3/00

BHI-EE-189 (12/97)

116-H-1 PRELIMINARY BOREHOLE RESULTS

[redacted]										
BOY2B4	Equipment	0.837	U	U	U	U	U	-0.014	0.138	-0.065
BOY270	2.5-4.5	0.708	1.4	33.5	50.6	4.18	U	0.543	0.459	1.84
BOY272	6.0-7.7	0.359	0.481	29.8	5.79	0.497	U	0.299	0.499	1.66
BOY2B2	DUPLICA	7.98	0.459	26.7	5.46	0.728	U	0.281	0.35	1.65
BOY2B3	SPLIT	U	0.456	27.4	5	U	U	0.453	0.543	2.15
BOY274	10.2-11.6	0.623	U	0.151	0.486	U	U	0.022	0.461	1.23
BOY276	13.2-15.0	-1	U	0.08	0.258	U	U	0.004	0.747	1.42
BOY278	16.5-18.5	-0.237	U	U	0.156	U	U	-0.017	0.28	1.54
BOY280	19.3-21.3	0.77	U	U	0.13	U	U	-0.023	0.317	1.31
BOY282	23.0-24.8	-0.649	U	U	U	U	U	-0.004	0.24	1.16
BOY284	25.8-27.8	-1.27	U	U	0.066	U	U	-0.024	0.28	0.765

[redacted]					
BOY2B4	Equipment	2.9	U	U	NA
BOY270	2.5-4.5	16.6	0.12	U	5.3
BOY272	6.0-7.7	2.6	0.06	U	2.1
BOY2B2	DUPLICA	1.6	0.08	U	NA
BOY2B3	SPLIT	2.3	0.02	0.16	NA
BOY274	10.2-11.6	2.4	U	U	2.1
BOY276	13.2-15.0	1.7	U	U	2.6
BOY278	16.5-18.5	1.7	U	U	1.7
BOY280	19.3-21.3	2.7	U	0.47	3.4
BOY282	23.0-24.8	4.1	0.02	0.59	6.4
BOY284	25.8-27.8	U	U	U	NA

Attachment 8

Waste Site: 116-DR-4 Pluto Crib	BACKFILL CONCURRENCE CHECKLIST (Concurrence to Proceed with Waste Site Backfill Operations)	WIDS No.: 116-DR-4

This checklist is a summary of cleanup verification results for the 116-DR-4 Pluto Crib. The checklist is intended as an agreement allowing the ERC subcontractor to backfill this site prior to the issuance of the final cleanup verification package. The lead regulatory agency has been provided copies of detailed calculations. The results are summarized below.

Regulatory Requirement	Remedial Action Goals (RAG)	Results	RAG Attained	Ref.
Direct Exposure – Radionuclides	1. Attain 15 mrem/yr dose rate above background over 1000 years.	1. Maximum dose calculated by RESRAD is 1.10 mrem/yr.	Yes	A
Direct Exposure – Nonradionuclides	1. Attain individual COC RAGs.	1. All individual COC concentrations are below the RAGS.	Yes	B
Meet Nonradionuclide Risk Requirements	1. Hazard quotient ratio of <1 for noncarcinogens.	1. All hazard quotient ratios are below 1.	Yes	B
	2. Cumulative hazard quotient ratio of <1 for noncarcinogens.	2. Cumulative hazard quotient ratio is less than 1 for noncarcinogens.		B
	3. Excess cancer risk of $<1 \times 10^{-6}$ for individual carcinogens.	3. Excess cancer risk for individual carcinogens are all less than 1×10^{-6}.		B
	4. Attain a cumulative excess cancer risk of $<1 \times 10^{-5}$ for carcinogens.	4. Cumulative excess cancer risk is less than 1×10^{-5} for carcinogens.		B
Groundwater/River Protection – Radionuclides	1. Attain single COC groundwater & river RAGS.	1. All single COC Groundwater and river RAGs have been attained.	Yes	C
	2. Attain National Primary Drinking Water Regulations 4-mrem/yr (beta/gamma) dose standard to target receptor/organ.	2. All organ specific doses are below the 4-mrem/yr dose standard.		C
	3. Meet National Primary Drinking Water Regulations 15 pCi/L (alpha activity) standard.	3. Alpha emitters are not a COC for the 116-DR-4 site, therefore alpha activity is 0 pCi/L for all years.		C
Groundwater/River Protection – Nonradionuclides	1. Attain individual nonradionuclide groundwater & river RAGs.	1. All the groundwater and river RAGs have been attained.	Yes	B
Other Supporting Information	1. Sample variance calculation			D
	2. Sample location design			E

All citations above and references on attached sheet are on record with Bechtel Hanford, Inc., Document and Information Services. Above noted regulatory requirements have been attained.					
	6/22/00	3M Corpuz	6/23/00		6/27/00
BHI Task Manager	Date	BHI Project Engineer	Date	DOE Project Manager	Date
Given the attached information, DOE can proceed with backfill of the site with minimal risk. Final approval that the site has met RAOs and RAGs will occur with the submittal, review, and approval of the Cleanup Verification Package by the lead regulatory agency.					
N/A	N/A				6-30-00
EPA Project Manager	Date			Ecology Project Manager	Date

Backfill Concurrence Checklist Attachments/References

Attachment/ Reference	Description
A	116-DR-4 Cleanup Verification RESRAD Calculations, 0100D-CA-N0039, Rev. 0
B	116-DR-4 95% UCL Calculations for Compliance with Cleanup Standards (Shallow Zone), 0100D-CA-V0149, Rev. 0
C	116-DR-4 Comparison to Drinking Water Standards, 0100D-CA-V0151, Rev. 0
D	116-DR-4 Pluto Crib Sample Variance, 0100D-CA-V0104, Rev. 0
E	116-DR-4 Shallow Zone Sample Location Design, 0100D-CA-V0103, Rev. 0

Waste Site: 116-DR-6 Liquid Disposal Trench	**BACKFILL CONCURRENCE CHECKLIST** (Concurrence to Proceed with Waste Site Backfill Operations)	WIDS No.: 116-DR-6

This checklist is a summary of cleanup verification results for the 116-DR-6 Liquid Disposal Trench. The checklist is intended as an agreement allowing the ERC subcontractor to backfill this site prior to the issuance of the final cleanup verification package. The lead regulatory agency has been provided copies of detailed calculations. The results are summarized below.

Regulatory Requirement	Remedial Action Goals (RAG)	Results	RAG Attained	Ref.
Direct Exposure – Radionuclides	1. Attain 15 mrem/yr dose rate above background over 1000 years.	1. Maximum dose calculated by RESRAD is 3.36 mrem/yr.	Yes	A
Direct Exposure – Nonradionuclides	1. Attain individual COC RAGs.	1. All individual COC concentrations are below the RAGS.	Yes	B
Meet Nonradionuclide Risk Requirements	1. Hazard quotient ratio of <1 for noncarcinogens.	1. All hazard quotient ratios are below 1.	Yes	B
	2. Cumulative hazard quotient ratio of <1 for noncarcinogens.	2. Cumulative hazard quotient ratio is less than 1 for noncarcinogens.		B
	3. Excess cancer risk of <1 x 10^{-6} for individual carcinogens.	3. Excess cancer risk for individual carcinogens are all less than 1 x 10^{-6}.		B
	4. Attain a cumulative excess cancer risk of <1 x 10^{-5} for carcinogens.	4. Cumulative excess cancer risk is less than 1 x 10^{-5} for carcinogens.		B
Groundwater/River Protection – Radionuclides	1. Attain single COC groundwater & river RAGS.	1. All single COC Groundwater and river RAGs have been attained.	Yes	C
	2. Attain National Primary Drinking Water Regulations 4-mrem/yr (beta/gamma) dose standard to target receptor/organ.	2. All organ specific doses are below the 4-mrem/yr dose standard.		C
	3. Meet National Primary Drinking Water Regulations 15 pCi/L (alpha activity) standard.	3. Alpha emitters are not a COC for the 116-DR-6 site, therefore alpha activity is 0 pCi/L for all years.		C
Groundwater/River Protection – Nonradionuclides	1. Attain individual nonradionuclide groundwater & river RAGs.	1. All the groundwater and river RAGs have been attained.	Yes	B
Other Supporting Information	1. Sample variance calculation			D
	2. Sample location design			E

All citations above and references on attached sheet are on record with Bechtel Hanford, Inc., Document and Information Services. Above noted regulatory requirements have been attained.

A L Langstaff	6/22/00	3M Corpus	6/23/00		6/21/00
BHI Task Manager	Date	BHI Project Engineer	Date	DOE Project Manager	Date

Given the attached information, DOE can proceed with backfill of the site with minimal risk. Final approval that the site has met RAOs and RAGs will occur with the submittal, review, and approval of the Cleanup Verification Package by the lead regulatory agency.

N/A	N/A		6-30-00
EPA Project Manager	Date	Ecology Project Manager	Date

Backfill Concurrence Checklist Attachments/References

Attachment/ Reference	Description
A	116-DR-6 Cleanup Verification RESRAD Calculations, 0100D-CA-N0038, Rev. 0
B	116-DR-6 95% UCL Calcs. for Compliance with Cleanup Standards (Shallow and Deep Zone), 0100D-CA-V0148, Rev. 0
C	116-DR-6 Comparison to Drinking Water Standards, 0100D-CA-V0150, Rev. 0
D	116-DR-6 Trench Sample Variance, 0100D-CA-V0106, Rev. 0
E	116-DR-6 Shallow & Deep Zone Sample Location Design, 0100D-CA-V0105, Rev. 0

Interim Action Waste Management Plan for the 100-NR-2 Operable Unit

DOE/RL-2000-41
Rev. 0

Interim Action Waste Management Plan for the 100-NR-2 Operable Unit

United States
Department of Energy

DOE/RL-2000-41
Rev. 0
OU: 100-NR-2
TSD: N/A
ERA: N/A

CONCURRENCE PAGE

Title: Interim Action Waste Management Plan for the 100-NR-2 Operable Unit

Concurrence: A. C. Tortoso
U.S. Department of Energy, Richland Operations Office

A. C. Tortoso — 7/20/00

Signature — Date

F. W. Bond
Washington State Department of Ecology

Fred W. Bond — 7/20/00

Signature — Date

DOE/RL-2000-41
Rev. 0

Interim Action Waste Management Plan for the 100-NR-2 Operable Unit

July 2000

TABLE OF CONTENTS

FIGURE

APPENDIX

ACRONYMS

CFR	*Code of Federal Regulations*
CWC	Central Waste Complex
DOE	U.S. Department of Energy
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
ERC	Environmental Restoration Contractor
ERDF	Environmental Restoration Disposal Facility
ETF	Effluent Treatment Facility
PSTF	Purgewater Storage and Treatment Facility
RCF	Radiological Counting Facility
WAC	*Washington Administrative Code*

1.0 PURPOSE

This interim action waste management plan establishes the requirements for the management and disposal of waste associated with the interim actions as stipulated in the *Interim Remedial Action Record of Decision for the 100-NR-1 and 100-NR-2 Operable Units* (EPA 1999a). Wastes associated with 100-NR-1 Operable Unit soil interim actions are covered under a separate waste management plan. The interim action for 100-NR-2 Operable Unit involves pumping groundwater from selected well locations, treating the water to remove strontium-90 by absorption, and re-injecting the treated water to the aquifer through upgradient injection wells. The ion-exchange media (resin) is a natural zeolite (clinopilolite, or "clino"). This waste management plan supercedes previously issued waste control plans for the 100-NR-2 Operable Unit and the pump-and-treat system.

This document also includes the requirements for the management and disposal of waste generated from activities such as monitoring conducted at operable unit groundwater wells, seeps, and/or aquifer sampling tubes. The groundwater wells, seeps, and aquifer tubes that provide information to support the 100-NR-2 Operable Unit are covered under this waste management plan. These wells are identified in Appendix A and include wells required to monitor the 100-NR-2 pump-and-treat system performance, the *Resource Conservation and Recovery Act of 1976* treatment, storage, and disposal units, including the post-remediation groundwater monitoring required by the 100-NR-1 Record of Decision (EPA 1999b), and the overall migration of contaminants within the operable unit.

Information concerning the pump-and-treat and groundwater monitoring is contained in the following documents:

- NPL Agreement/Change Control Form 113 (DOE-RL and Ecology 1997)
- Federal Facility Agreement and Consent Order Change Control Form M-15-96-08 (DOE-RL and Ecology 1996)
- *N-Springs Expedited Response Action Performance Evaluation Report*, DOE/RL-95-110 (DOE-RL 1996)
- *Groundwater Monitoring Plan for the 1301-N, 1325-N, and 1324N/NA Sites* (PNNL 1996).

The activities that will likely generate waste include, but are not limited to, the following:

- Construction, operation, maintenance, and decommissioning of the groundwater remediation systems
- Groundwater well or aquifer tube installation

- Groundwater well or aquifer tube development, sampling, maintenance, and decommissioning
- Water-level and other in situ groundwater measurements
- Seep sampling
- Process sampling and screening/analysis of samples
- Decontamination of equipment and material
- Aquifer testing, geophysical logging, and treatability studies (see note below).

NOTE: Testing, treatability studies, or other special activities not specifically identified in the above referenced documents will be evaluated with the regulatory agencies for coverage under this plan. A supplement to this document or a separate waste management plan or waste control plan prepared in accordance with the *Environmental Restoration Program Strategy for Management of Investigation-Derived Waste* (Ecology et al. 1999) may be required.

Environmental Restoration Contractor (ERC) site-specific waste management instruction(s) will be developed, as needed, for the various activities identified above in order to implement the requirements identified in the following sections.

2.0 PROJECTED WASTE STREAMS

Projected waste streams include the following:

- Drill cuttings (both dry soil and saturated slurries)
- Spent resins and filter elements
- Liquids including, but not limited to, the following:
  - Purgewater generated during well installation or aquifer tube installation, development, testing, monitoring, maintenance, decommissioning, and decanting of saturated soils
  - Water from slurry pumping and gravity-draining resins
  - Decontamination fluids
  - Process sampling and screening analysis liquids

- Water from unplanned releases (i.e., spills)

- Miscellaneous solid waste including, but not limited to, the following:
  - Filter paper, syringes, wipes, personal protective equipment, cloth, plastic, equipment, tools, pumps, wire, metal and plastic piping, and materials from cleanup of unplanned releases

- Decommissioning debris such as concrete, wood, rebar, metal/plastic pipe and screens, wire, bentontite/sand/gravel, equipment, pumps, and tanks

- Spent/excess chemicals/reagent and used oil

- Sample-related waste from sample analysis/screening activities of 100-NR-2 materials that are conducted at the 200-ZP-1 mobile laboratory and the Radiological Counting Facility (RCF).

3.0 WASTE DESIGNATION AND DISPOSAL

Waste will be designated in accordance with *Washington Administrative Code* (WAC) 173-303 using process knowledge, historical analytical data, and/or analyses of samples as identified in the referenced documents or sampling and analysis plans, as appropriate. The 100-NR-2 Operable Unit has an extensive groundwater well and aquifer sampling tube network. Several years of characterization data and pump-and-treat system operation data have been obtained that can be used as the basis for waste designation.

Groundwater associated with the 100-NR-2 Operable Unit is currently assumed to contain spent methanol, which is a "F003" listed waste. The groundwater is assumed to contain spent methanol based upon assumed discharges of spent methanol to the 116-N-1 (1301 N) and 116-N-3 (1325 N) Liquid Waste Disposal Facilities. Methanol has not been detected in the groundwater and a "contained-in" determination is being pursued to demonstrate that the groundwater does not contain methanol. If a "contained-in" determination is approved by the Washington State Department of Ecology (Ecology), the groundwater and any other media, debris, or material that come into contact with the groundwater will not be assigned the "F003" listed waste code.

Until the "contained-in" determination is approved, extracted groundwater, spent resins, and other materials that come into contact with the groundwater within the limits of the strontium-90 plume will be assigned the "F003" listed waste code. Because strontium-90 is present throughout a large portion of the 100-NR-2 Operable Unit, the majority of the waste will also be designated as containing radiological materials.

The resins, filters, drill cuttings, and most of the other miscellaneous solid waste will be disposed at the Environmental Restoration Disposal Facility (ERDF) if it meets the waste acceptance criteria or if the materials can be treated to meet the criteria. Wastes may be treated at the operable unit or at the ERDF to meet the disposal facility's waste acceptance criteria. The U.S. Environmental Protection Agency (EPA) and Ecology shall approve any treatment necessary to meet the disposal facility's waste acceptance criteria. The ERDF is the preferred disposal location, provided that the waste acceptance criteria are met. Waste that does not meet the acceptance criteria may be stored at the Central Waste Complex (CWC) or sent offsite for disposal, as appropriate, as authorized by the regulatory agency.

Miscellaneous solid waste and demolition debris that have contacted contaminated media may be disposed at the ERDF, as described above. Miscellaneous solid waste or demolition debris that are nondangerous and have been radiologically released may be disposed at an offsite solid waste landfill or an onsite demolition landfill (for demolition waste), as appropriate. Nondangerous, uncontaminated soils and slurries will be placed on the ground near the point of generation. Waste handling and disposal options are further described in Section 4.0.

Contaminated liquids will be returned to the influent side of the pump-and-treat system or will be sent to the Purgewater Storage and Treatment Facility (PSTF) or the Effluent Treatment Facility (ETF), as appropriate. Small volumes of liquid that have been stabilized may also be disposed at the ERDF if the waste meets the ERDF waste acceptance criteria. Liquid waste that does not meet the acceptance criteria for any of these facilities may be stored at the CWC (mixed waste) or sent offsite for disposal (nonradioactive waste), as authorized by the regulatory agency. Used oil will be sent offsite for recycling or disposal. Spent or unusable chemicals/reagents may also be generated during field sampling and analysis and will require disposal based on the designation. Liquids such as purgewater or decontamination fluids that are nondangerous liquids below purgewater collection criteria (Izatt 1990) may be discharged to the ground.

Offsite facilities that receive contaminated waste must be deemed acceptable by the EPA in accordance with 40 *Code of Federal Regulations* (CFR) 300.440. The exception is used oil, expired/excess chemicals, and solid waste that has not contacted contaminated media and that is sent for recycling or disposal at an offsite solid waste landfill. An offsite determination is also required prior to shipment of waste to the CWC.

4.0 WASTE STREAM-SPECIFIC MANAGEMENT

This section describes how the various waste streams will be managed.

4.1 DRILL CUTTINGS

Drill cuttings (soils and slurries) from outside an area of known or suspected contamination will be collected in stockpiles near the point of generation. Soils and slurries from known or suspect contaminated areas will be placed on a tarp or containerized. Contained soil slurries will be decanted and free liquids remaining in the container will be eliminated by evaporation and/or the addition of sorbent material prior to disposal, as necessary. Decanted water will be managed as purgewater. Soils and slurries that do not designate as a dangerous waste, are below *Model Toxics Control Act* (MTCA) B soils cleanup standards, and that have been released from a radiological perspective may be placed on the ground near the point of generation. Decanting slurries and eliminating free liquids is authorized without prior approval.

4.2 SPENT RESINS AND FILTER ELEMENTS

A natural zeolite (clinoptilolite) absoption technology is used in the pump-and-treat system to remove the strontium-90. The pump-and-treat system is designed with in-line filters to collect fine particulates present in the groundwater. Fine particles collect on filters located in the filter housings. The filter elements are removed from the filter housing and replaced as needed to maintain system efficiency. The spent resin and filters are dewatered and transferred into containers for shipment to the ERDF.

4.3 LIQUIDS

Various liquid wastes are generated from operation and maintenance of the pump-and-treat systems and groundwater well-related activities (as described in Section 2.0). Liquid waste streams will be processed through the 100-NR-2 pump-and-treat system if technically feasible to do so. Introduction of contamination that is not found in the specific operable unit is not allowed. Only unaltered liquids will be returned to the system. Fluids that contain additives (e.g., fluids used for decontamination or reagents added for field screening or analysis) will not be allowed. Introduction of liquid containing algae growth into the treatment system should be avoided. Groundwater containing petroleum products is also not allowed.

4.3.1 Purgewater

Purgewater is generated during well or aquifer tube installation, development, testing, monitoring, sampling, maintenance, and decanting of saturated soils during drilling activities. Purgewater from the strontium-90 plume is currently considered to contain an "F003" listed dangerous waste and will be collected and contained at the well head or pump-and-treat system, if necessary, until placed into the influent side of the pump-and-treat system or transported to the PTSF or the ETF. Upon approval of a "contained-in" determination, purgewater will no longer be considered to contain an "F003" listed dangerous waste. Nondanagerous purgewater below the collection criteria may be discharged to the ground outside areas of known or suspected surface/vadose zone contamination. Purgewater above the collection criteria will be collected, contained, and placed into the influent side of the pump-and-treat system or transported to the PTSF or the ETF.

4.3.2 Water from Slurry Pumping and Gravity-Draining Resins

Water is generated during slurry pumping and gravity-draining of resins. The liquid is pumped back into the influent side of the pump-and-treat system. Water generated during the de-watering of filter elements is also returned to the pump-and-treat system.

4.3.3 Liquids from Unplanned Releases

Water generated from unplanned releases that is contained within the pump-and-treat system will be returned to influent side of the pump-and-treat system, if appropriate, or transported to the PSTF or ETF. If a release occurs, notification to ERC Regulatory Support, 373-4314, is required. The reporting requirements will be meet as required by U.S. Department of Energy (DOE) O 232.1A. The ERC spill reporting point of contact will determine the actions necessary to address the spill. The regulatory agency will be notified of significant spills.

If a significant unplanned release of the influent occurred, it would be detected by the influent flow meters. If the measured flow differs by 2 gal/min between the well head and the influent manifold flow meter, the system will automatically shut down the pump for the individual extraction well.

4.3.4 Decontamination Fluids

Decontamination fluids (i.e., water and/or nonhazardous cleaning solutions) generated from cleaning equipment and tools used in the operable units will be discharged to the ground if it is nondangerous and below purgewater collection criteria. Decontamination fluids above the collection criteria will be contained and transported to the PSTF, ETF (if the waste acceptance criteria can be met), or other facility as authorized by the lead regulatory agency. Small volumes of decontamination fluids may be stabilized to eliminate free liquids and then disposed to ERDF if the waste acceptance criteria can be met.

Decontamination of some equipment (e.g., split spoon samplers) may be conducted at either the 600 Area centralized location and/or the Waste Sampling and Characterization Facility because decontamination and containment systems are already established at these locations. The waste generated at these facilities will be managed in accordance with applicable regulations and the facilities' waste management procedures.

4.3.5 Sample Analysis and Screening Liquids

Unaltered liquid waste generated during sample screening and analysis will be managed as purgewater (as described in Section 4.3.1). Altered samples will be contained and disposed at the ETF, ERDF, or another appropriate facility, as authorized by the regulatory agency, depending on the waste designation. Some liquids may be neutralized and/or stabilized in order to meet the disposal facility's waste acceptance criteria.

4.4 MISCELLANEOUS SOLID WASTES

In addition to the spent resins and filter elements addressed in Section 4.1, other solid waste will be generated during all phases of remediation system operation and maintenance. Solid wastes are also generated during groundwater well-related activities. The wastes are described in Section 2.0. Miscellaneous solid waste will be placed in containers that are appropriate for the material and the disposal facility. Miscellaneous solid waste that has contacted contaminated media may be disposed at the ERDF if the ERDF waste acceptance criteria are met. This material may be packaged with the resin for disposal at the ERDF. If the waste acceptance criteria cannot be met, the waste will be shipped to the CWC for storage or to an offsite facility, as appropriate, depending on the waste designation. Miscellaneous solid waste that has not contacted contaminated media and miscellaneous solid waste that has contacted contaminated media and that is nondangerous and has been released for radionuclides, may be disposed at an offsite solid waste landfill or recycled, as appropriate.

4.5 DECOMMISSIONING DEBRIS

Decommissioning debris such as concrete, wood, rebar, metal/plastic pipe and screens, wire, bentontite/sand/gravel, equipment, and pumps is generated during the decommissioning of wells. Debris that has contacted contaminated media may be disposed at the ERDF if the ERDF waste acceptance criteria are met or at another onsite or offsite approved facility if the waste acceptance criteria cannot be met. Contact debris that is nondangerous and radiologically released or solid waste that has not contacted potentially contaminated materials will be disposed offsite at a solid waste landfill or an onsite demolition landfill or recycled, as appropriate.

4.6 SPENT OR UNUSABLE CHEMICALS/REAGENTS, USED OIL, AND RETURNED SAMPLE WASTE

Used oil is generated during the operation of the pump-and-treat system and will be sent offsite for recycling or disposal, as appropriate. Spent/unusable (e.g., expired) chemicals that are generated during the implementation of the interim action will be managed and disposed as appropriate for the specific chemical or reagent. Screening and analysis of both solids and liquids may be conducted at the pump-and-treat systems, 200-ZP-1 mobile sample laboratory and/or the RCF. The 200-ZP-1 mobile sample laboratory samples and associated waste, and the RCF samples are authorized for return to the specific pump-and-treat system for temporary storage pending disposal in accordance with this plan.

5.0 PACKAGING AND LABELING

Materials requiring collection will be placed in containers appropriate for the material and the receiving facility. Drums may be used for some materials (e.g., drill cuttings). However, packaging for large/irregular waste (e.g., casing) or large-volume waste (e.g., resin) may include containment other than drums. The packaging shall ensure that contaminants do not migrate and protect against environmental degradation. The packaging may include, but is not limited to, plastic wrap, 4-ft by 4-ft by 8-ft boxes, and ERDF or similar containers.

Low-volume miscellaneous materials associated with activities such as groundwater well sampling may be bagged, taped, and labeled with the well number at the well head. The bagged material will be transported in a protective manner (i.e., containment of the material is maintained) with the workers while proceeding from well to well in the operable unit. Upon arrival at the storage location, the materials will be placed in an accumulation drum and managed as waste within the operable unit. The materials may also be disposed directly to ERDF without storage, as appropriate.

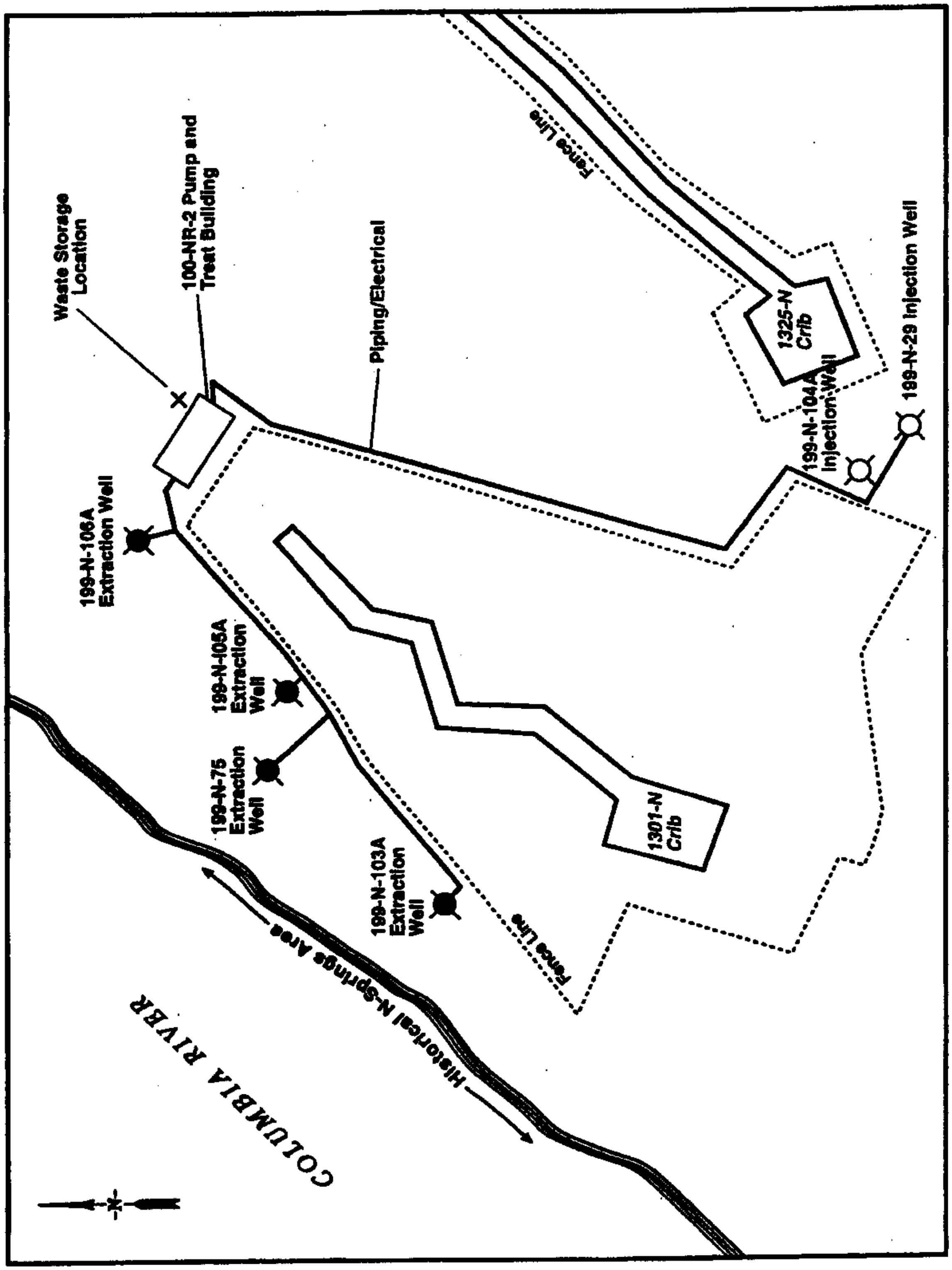
Packaging and labeling during storage and transportation must meet WAC 173-303 and U.S. Department of Transportation requirements, as appropriate. Packaging exceptions to U.S. Department of Transportation requirements that are documented and provide an equivalent degree of safety during transportation may be used for onsite waste shipments. Containers will be labeled and marked appropriately to match the designation established for each waste stream. The containers will be labeled as containing remediation waste. If investigation-derived waste (IDW) is managed under this plan, it will be labeled as containing IDW. The containers will be sealed and shipped to the identified disposal facility.

6.0 STORAGE/TRANSPORATION

The amount of waste stored at the site should be kept to a minimum. Full containers should be prepared for disposal as quickly as economically feasible. Any designated dangerous waste will be stored in a temporary storage area meeting the substantive requirements of WAC 173-303-630 and will be inspected weekly. The waste will be stored at the 100-NR-2 pump-and-treat system at the area designated to store waste (Figure 1). Some waste (e.g., drill cuttings) may be temporarily accumulated near the point of generation. Any IDW that is generated under this plan may be stored for up to 6 months. An extension is required to be approved by Ecology for storage of IDW beyond 6 months.

Radioactive waste will be managed separately from non-radioactive waste. Container tracking and traceability will be controlled through the Hanford Site Solid Waste Information and Tracking System. The containers will be sealed and shipped to the identified disposal facility. Waste will be transported in accordance with WAC 173-303 and U.S. Department of Transportation Requirements, as appropriate.

Figure 1. 100-NR-2 Waste Storage Location.



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APPENDIX A

100-NR-2 WELLS

APPENDIX A

100-NR-2 WELLS

199-N-103A	199-N104A	199-N105A
199-N106A	199-N-14	199-N-16
199-N-18	199-N-19	199-N-2
199-N-21	199-N-22	199-N-26
199-N-27	199-N-28	199-N-29
199-N-3	199-N-32	199-N-34
199-N-41	199-N-42	199-N-49
199-N-50	199-N-51	199-N-52
199-N-57	199-N-59	199-N-62
199-N-64	199-N-67	199-N-70
199-N-71	199-N-72	199-N-73
199-N-74	199-N-75	199-N-76
199-N-77	199-N-80	199-N-81
199-N-8S		

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Data Quality Objectives Summary Report for the 100-NR-1 Treatment, Storage, and Disposal Unit

BHI-01293
Rev. 0

Data Quality Objectives Summary Report for the 100-NR-1 Treatment, Storage, and Disposal Units

Prepared for the U.S. Department of Energy, Richland Operations Office
Office of Environmental Restoration

Submitted by: Bechtel Hanford, Inc.

BHI-01293
Rev. 0
OU: 100-NR-1
TSD: 100-NR-1
ERA: N/A

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Signature 3/14/00
Date

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Rev. 0

Data Quality Objectives Summary Report for the 100-NR-1 Treatment, Storage, and Disposal Units

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Date Published

March 2000

EXECUTIVE SUMMARY

This data quality objective (DQO) summary report has been developed to support sampling and analysis of the 100-NR-1 Operable Unit treatment, storage, and disposal units during remediation and for closeout of the sites. The DQOs established by this document can be achieved by a judgmentally based sample design for the purpose of waste designation. Statistically based sampling will be used for the purpose of sampling the sites for closeout.

CONTENTS

APPENDIX

FIGURES

TABLES

TABLES (cont.)

ACRONYMS

AA	alternative action
AEA	alpha energy analysis
ARAR	applicable or relevant and appropriate requirement
bgs	below ground surface
BHI	Bechtel Hanford, Inc.
CHI	CH2M Hill Hanford, Inc.
CVAA	cold vapor atomic absorption
DR	decision rule
DS	decision statement
CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
CFR	*Code of Federal Regulations*
CMS	corrective measures study
COC	contaminant of concern
COPC	contaminant of potential concern
DQO	data quality objective
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
ERDF	Environmental Restoration Disposal Facility
GeLi	germanium-lithium
HPGe	high-purity germanium
ICP	inductively coupled plasma
MCL	maximum contaminant level
MDL	minimum detection limit
MTCA	*Model Toxics Control Act*
NaI	sodium iodide
PQL	practical quantitation limit
PRG	preliminary remediation goal
PSQ	principal study question
RAG	remedial action goal
RAO	remedial action objective
RESRAD	RESidual RADioactivity dose model
RCRA	*Resource Conservation and Recovery Act of 1976*
RL	U.S. Department of Energy, Richland Operations Office
ROD	Record of Decision
RSD	relative standard deviation
TCLP	toxicity characteristic leachate procedure
TSD	treatment, storage, and disposal
OU	operable unit
UCL	upper confidence limit
WAC	*Washington Administrative Code*
WS	waste stream
XRF	x-ray fluorescence

METRIC CONVERSION CHART

The following conversion chart is provided to aid the reader in conversion.

Into Metric Units			Out of Metric Units		
If You Know	*Multiply By*	*To Get*	*If You Know*	*Multiply By*	*To Get*
Length			**Length**		
inches	25.4	millimeters	millimeters	0.039	inches
inches	2.54	centimeters	centimeters	0.394	inches
feet	0.305	meters	meters	3.281	feet
yards	0.914	meters	meters	1.094	yards
miles	1.609	kilometers	kilometers	0.621	miles
Area			**Area**		
sq. inches	6.452	sq. centimeters	sq. centimeters	0.155	sq. inches
sq. feet	0.093	sq. meters	sq. meters	10.76	sq. feet
sq. yards	0.0836	sq. meters	sq. meters	1.196	sq. yards
sq. miles	2.6	sq. kilometers	sq. kilometers	0.4	sq. miles
acres	0.405	hectares	hectares	2.47	acres
Mass (weight)			**Mass (weight)**		
ounces	28.35	grams	grams	0.035	ounces
pounds	0.454	kilograms	kilograms	2.205	pounds
ton	0.907	metric ton	metric ton	1.102	ton
Volume			**Volume**		
teaspoons	5	milliliters	milliliters	0.033	fluid ounces
tablespoons	15	milliliters	liters	2.1	pints
fluid ounces	30	milliliters	liters	1.057	quarts
cups	0.24	liters	liters	0.264	gallons
pints	0.47	liters	cubic meters	35.315	cubic feet
quarts	0.95	liters	cubic meters	1.308	cubic yards
gallons	3.8	liters			
cubic feet	0.028	cubic meters			
cubic yards	0.765	cubic meters			
Temperature			**Temperature**		
Fahrenheit	subtract 32, then multiply by 5/9	Celsius	Celsius	multiply by 9/5, then add 32	Fahrenheit
Radioactivity			**Radioactivity**		
picocuries	37	millibecquerel	millibecquerel	0.027	picocuries

1.0 STEP 1 – STATE THE PROBLEM

1.1 INTRODUCTION

Remedial actions will address contaminated soils, structures, and pipelines associated with four *Resource Conservation and Recovery Act of 1976* (RCRA) treatment, storage, and disposal (TSD) units and two associated sites. These TSD units and associated sites are located on the Hanford Site, near the Columbia River in the 100-NR-1 Operable Unit (OU).

The response actions are being taken under the authority of RCRA corrective action (Section 3004[u]); RCRA closure (Section 3005[e]); and the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) remedial action (Section 121). By applying CERCLA authority jointly with that of RCRA, additional options for disposal of corrective action and remedial action wastes at the Environmental Restoration Disposal Facility (ERDF) are possible. The regulatory background has been detailed in a corrective measures study (CMS)/closure plan (DOE-RL 1998a).

1.2 FACILITY DESCRIPTIONS AND PROCESS HISTORY

Descriptions and process history information for each of the TSD units addressed by this data quality objective (DQO) summary report are provided in the following subsections. Figure 1-1 provides a map showing the locations of the TSD units.

Nine water-cooled, graphite-moderated, plutonium-production reactors were constructed along the Columbia River at the Hanford Site from 1943 to 1963. The 100-N Reactor, the last reactor to be built, is located in the 100 Areas in the northern part of the Hanford Site, on a broad strip of land along the Columbia River, about 48 km (30 mi) northwest of the city of Richland, Washington. The 100-N Reactor differs from the other reactors at the Hanford Site not only because of its closed-loop cooling system, but because it was designed as a dual-purpose reactor, capable of producing both special nuclear material and steam generation for electrical power. Although referred to as a "closed-loop cooling system," the system actually operated as a bleed-and-feed system where a portion of the cooling waters were constantly bled-off and replaced with fresh demineralized water. The cooling effluent removed from the loop eventually made its way to the 116-N-1 and 116-N-3 Liquid Waste Disposal Facilities. The 100-N Reactor began production in December 1963. The Hanford Generating Plant was completed and started producing electrical power in April 1966. Both the reactor and the generating plant operated continuously until January 7, 1987, except during periodic shutdowns for maintenance and repairs. The reactor was retired in October 1989 (WHC 1994), and orders were received to shut down the reactor in October 1991.

1.2.1 116-N-1 Crib and Trench and 116-N-3 Crib and Trench

The 116-N-1 Crib and Trench and the 116-N-3 Crib and Trench received radioactive liquid wastes containing activation and fission products, as well as small quantities of corrosive liquids and laboratory chemicals generated by various N Reactor operations. The units used the vadose zone to remove radioactive and hazardous materials from the effluent generated from reactor operations. As discharged effluent percolated through the soil column, most radioactive and chemical constituents were retained in the soil through filtration, absorption, adsorption, and ion exchange. However, some constituents (e.g., tritium) were not retained in the soil but instead traveled with the effluent. Eventually the soil's capacity to remove contaminants from the effluent was exceeded, allowing more contaminants to travel to the groundwater and on to the Columbia River.

The primary waste sources were the reactor cooling systems and the fuel storage basins. Essentially all of the strontium-90 and cesium-137 discharged to the 116-N-1 unit originated in the 100-N Reactor fuel storage basin. The water was discharged to the liquid waste disposal facilities at an average flow rate of 6,800 L/min (1,800 gal/min).

Various dangerous waste solutions were disposed in the units. These wastes resulted mainly from decontamination of the primary coolant system and from the possible disposal of chemicals to common floor drains that discharged to the units (WHC 1994). The chemicals that were introduced into the primary coolant system were ammonium hydroxide and hydrazine. Analysis of the primary coolant wastewater in 1985 indicated that the wastewater did not exhibit any of the characteristics of a regulated dangerous waste. Releases from the periphery cooling systems resulted in small continuous discharges of a variety of chemicals to the units, including ammonium hydroxide, morpholine, and hydrazine. Sodium dichromate was used as a corrosion inhibitor in the reactor cooling system and was discharged to the 116-N-1 unit until the early 1970s. Other discharges included drainage from reactor support facilities, five wet laboratories, and the auxiliary power battery lockers. Additional information on the N Reactor waste-generating processes is presented in the *100-N Area Technical Baseline Report* (WHC 1994).

1.2.1.1 116-N-1 Crib and Trench. The 116-N-1 unit is composed of two parts: a crib and a zig-zag-shaped trench. The crib area is approximately 88-m (289-ft) long by 38-m (125-ft) wide. The bottom of the crib is approximately 1.5 m (5 ft) below the level of the surrounding grade. A sloped soil and gravel embankment forms the walls of the crib. The crib was originally excavated to a depth of about 4.6 m (15 ft) below the level of the surrounding grade. The crib has been backfilled at various times with boulders and cobbles to control the spread of contamination. The three distinct layers of backfill are (1) the lowest layer, which is 0.9-m (3-ft) thick and consists of large boulders; (2) the middle layer, which is 0.6-m (2-ft) thick and is composed of smaller boulders; and (3) the upper layer, which is 1.2- to 1.5-m (4- to 5-ft) thick and consists of cobble-sized material.

The 116-N-1 Trench is 490-m (1,608-ft) long by 15-m (49-ft) wide at the top, with sloped side walls. Water spilled over a weir box in the dike (located on the north side of the crib) and into the trench. Wooden poles laid across the trench were used to support wire screening to keep birds out. This system of poles and netting was not completely effective in preventing wildlife intrusion, and airborne spread of contamination was also a problem. In early 1982, pre-cast concrete panels were installed to cover the entire trench as a further step to minimize wildlife intrusion and airborne contamination. These panels created a 15-m (50-ft)-wide cover over the top of the trench. The wooden poles and wildlife netting were not removed during installation of the cover panels.

1.2.1.2 116-N-3 Crib and Trench. The 116-N-3 unit is composed of two parts: a crib and a straight trench. The 116-N-3 Crib began operation in October 1983 as a replacement for 116-N-1, which had reached its disposal capacity. The 116-N-3 Crib is 76 m by 73 m (249 ft by 240 ft) and is covered by pre-cast concrete panels. The cover is about 1 m (3 ft) below the surrounding surface grade, and the bottom of the crib is 2 m (7 ft) below the cover. A water distribution system in the form of a network of concrete troughs rests on the bottom of the crib.

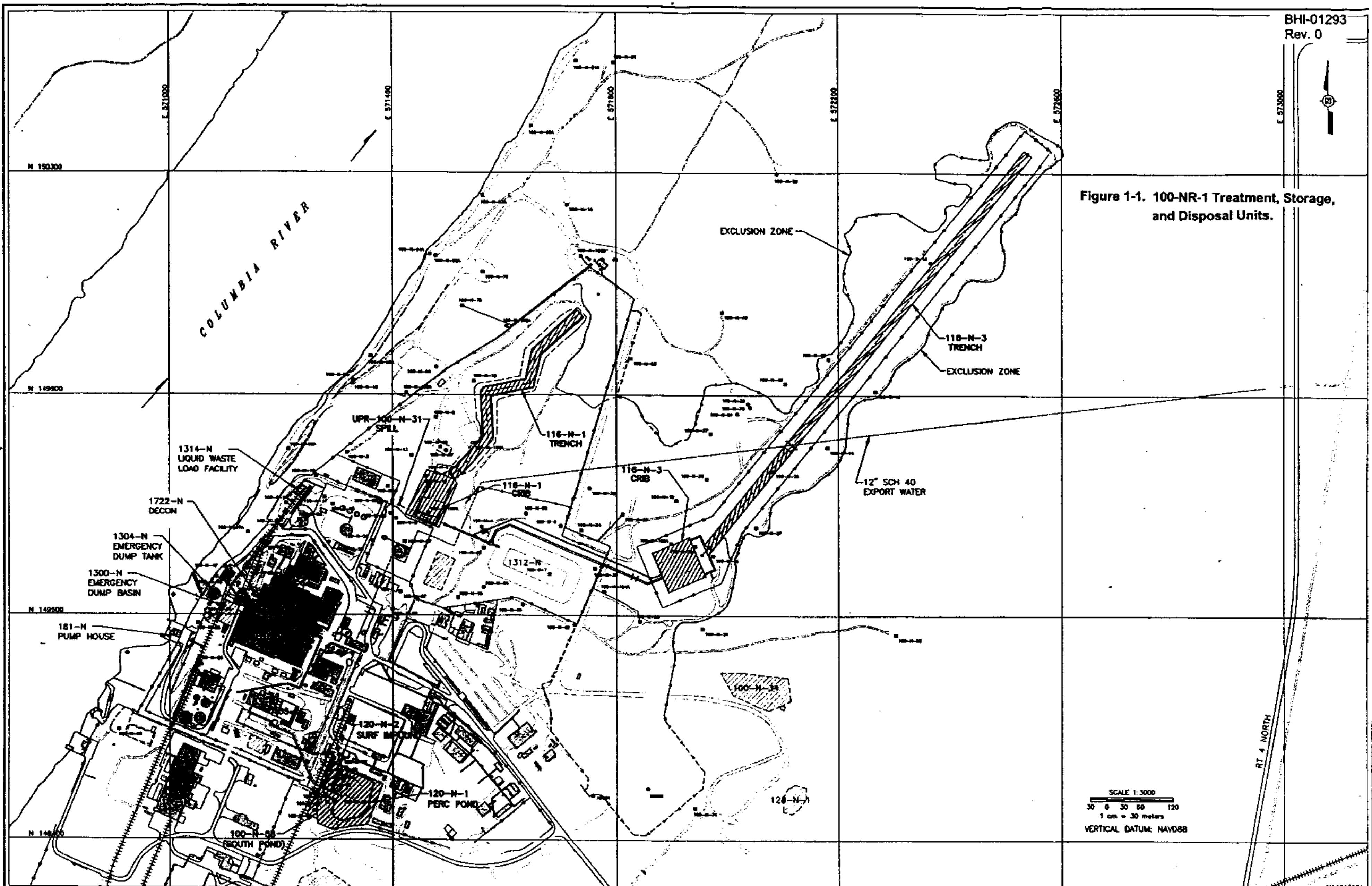


Figure 1-1. 100-NR-1 Treatment, Storage, and Disposal Units.

Water flowed from these troughs into the crib. Because of low percolation rates in the soil column, the 116-N-3 Crib was not able to achieve its designed flow capacity and the crib overflowed on two or three occasions. Each of the overflows traveled no more than 6 to 9 m (20 to 30 ft) from the concrete cover on the crib. All contamination remained within the fenced boundary, and each overflow was covered with a 15- to 20-cm (6- to 8-in.) layer of clean 2.5- to 5-cm (1- to 2-in.) river rock. After these initial incidents, the flow to 116-N-3 was controlled to prevent any further overflows.

Three months after the 116-N-3 Crib was placed into operation, the 116-N-3 straight extension trench was added. The trench ties into the crib at two points (from the crib's northern and eastern corners), with the effluent from these points combining in a common weir box. The tie-in is composed of rubber-gasket-joined, pre-cast, reinforced-concrete box sections. Effluent flowing through the weir box discharged into the trench through an overflow gate in the weir box. From the weir box, the trench extends about 914 m (3,000 ft) in a north-northeasterly direction.

The 116-N-3 Trench is 914-m (3,000-ft) long by 16.8-m (55-ft) wide and is covered with pre-cast concrete panels. Each panel is self-supporting and is approximately 17-m (55-ft) long and 3.1-m (10-ft) wide. The trench is divided into four equal-length sections by three dams. Only the first 226 m (740 ft) of the 116-N-3 Trench were used because effluent levels never rose high enough to cross the first dam. The dams are composed of structural fill and concrete. A layer of rip-rap was added on the downstream side of each dam to prevent scouring. The top 0.6 m (2 ft) of the trench bottom is a layer of 50- to 200-mm (2- to 8-in.) cobbles. The concrete panels are about 1 m (3 ft) below the surrounding grade, and the bottom of the trench is about 3 m (10 ft) below the concrete panels. The 116-N-3 straight extension trench was placed into full service in September 1985. In January 1987, N Reactor was placed on stand-down status for an extended maintenance and safety upgrade period, and the reactor was never restarted after that shutdown. Discharges to the 116-N-3 Trench decreased significantly at that time and ceased in April 1991.

1.2.2 Pipelines Associated with 116-N-1 and 116-N-3

Buried pipelines associated with the 116-N-1 and 116-N-3 sites consist of a total of 1,763 m (5,784 ft) of pipeline ranging in size from 8 to 91 cm (3.2 to 35.9 in.) in diameter, at an average depth of 3.7 m (12 ft). Because there is no process history indicating that the pipelines leaked, there is no known soil contamination associated with the pipelines. Nevertheless, it is possible that leaks have occurred but went undetected. The condition of the pipelines, internal contamination, and the extent and nature of any soil contamination that may be present will be assessed during the remedial design/remedial action phase of the project.

1.2.3 UPR-100-N-31

The UPR-100-N-31 spill occurred on July 22, 1974, while sample lines were being installed in a 15-cm (6-in.) steel casing through the berm on the west side of the 116-N-1 Crib. During the sample line installation, the water level in the crib was raised from 38 to 46 cm (15 to 18 in.) as a result of an emergency dump tank drawdown test. Due to the increased water level, approximately 4,000 L (1,056 gal) of effluent water containing fission and activation products flowed through the casing and were discharged to the soil. An area of approximately 188 m^2 (2,023 ft^2) was contaminated. Sand and fines were used to stabilize the soil contamination before its removal and disposal at the 200 Areas. After the contaminated soil was removed, clean fill material was used to restore the site. Some residual contamination may remain at this site because the cleanup that was performed in 1974 was not performed to today's cleanup standards.

1.2.4 120-N-1, 120-N-2, and 100-N-58 Percolation Pond System

The percolation pond system received nonradioactive liquid corrosive wastes from the 163-N Demineralization Plant and the 183-N Water Filter Plant. Before 1977, the effluent from 163-N Demineralization Plant was discharged to the Columbia River, which was the common practice of industry at that time. Beginning in 1977, the effluent was discharged to the 120-N-1 Percolation Pond. The *100-N Area Technical Baseline Report* (WHC 1994) summarizes the waste treatment practice as the alternate addition of acidic cation regenerate and alkaline anion regenerate to neutralize the pH of 163-N Demineralization Plant's effluent over time.

1.2.4.1 120-N-1 Percolation Pond. The 120-N-1 Percolation Pond has a capacity of 11.4 million L (3 million gal), and the bottom area is approximately 2,700 m^2 (29,052 ft^2). After treatment in the 120-N-2 Surface Impoundment (see Section 1.2.4.2), neutralized wastewater was transferred to the 120-N-1 Percolation Pond by a system of overflow and drain lines, where the effluent discharged to the soil column.

1.2.4.2 120-N-2 Surface Impoundment. The 120-N-2 Surface Impoundment is a double-lined pond (with two 1.1-mm [0.04-in.] liners) with a leachate collection system. The impoundment was built in the location of the old North Settling Pond, which had previously received corrosive waste and filter backwash water from the 163-N Demineralization Plant and the 183-N Water Filter Plant. The impoundment measures approximately 43 m by 23 m (141 ft by 75 ft) at the surface. The sides of the pond slope to the bottom, which measures approximately 24 m by 4.6 m (79 ft by 15 ft), and the pond has a design capacity of 1.6 million L (0.4 million gal).

1.2.4.3 100-N-58 Settling Pond. The 100-N-58 Settling Pond measured approximately 34 m by 15 m (112 ft by 49 ft) at the surface, with the sides sloping to the bottom and measuring approximately 24 m by 3 m (79 ft by 10 ft), and an estimated depth of 4.5 m (14.8 ft). The 100-N-58 Settling Pond originally received corrosive waste and filter backwash water from the 163-N Demineralization Plant and the 183-N Water Filter Plant in parallel with the 120-N-2 Pond. In 1983, when the liner was installed in the 120-N-2 Surface Impoundment, the 100-N-58 Settling Pond was backfilled to grade.

1.2.5 Pipelines Associated with the 120-N-1, 120-N-2, and 100-N-58 Percolation Pond System

Buried pipelines associated with the 120-N-1, 120-N-2, and 100-N-58 percolation pond system consist of approximately 296 m (971 ft) of pipeline ranging in size from 20 to 30 cm (8 to 12 in.) in diameter, at an average depth of 3.7 m (12 ft). Several pipelines that were removed from service were likely abandoned in place.

1.3 PROJECT GOALS

The purpose of the project is to remediate the 100-NR-1 TSD sites identified in the 100-NR-1 interim remedial action Record of Decision (ROD) (Ecology et al. 2000) that have received radioactive waste (i.e., the 116-N-1, 116-N-3, associated pipelines, and UPR-100-N-31). The selected remedy includes excavation, waste disposal, and backfill of the waste sites. This project will not implement work that is outside of the scope of the interim remedial action ROD or the CMS/closure plan (DOE-RL 1998a) for the nonradioactive sites.

The project goals are as follows:

- Remove soils that exceed direct exposure remedial action objectives (RAOs) for rural-residential exposure up to a depth of 4.6 m (15 ft) below surrounding grade or to the bottom of the engineered structure, whichever is deeper. The RAOs for rural-residential exposure are 15 mrem/yr above natural background for radionuclides and the State of Washington's *Model Toxics Control Act* [MTCA] Method B values for nonradioactive contaminants (*Washington Administrative Code* [WAC] 173-340).

- Remove soils to a depth of 1.5 m (5 ft) below the engineered structures of the 116-N-1 and 116-N-3 units that contain plutonium-239/240 contaminants greater than 15 mrem/yr above natural background.

- Remove soils that exceed standards for the protection of groundwater and the Columbia River. For sites where soil contamination in excess of the groundwater or river cleanup standards is present more than 4.6 m (15 ft) below surrounding grade, several balancing factors will be considered to determine the extent of additional remediation. These factors include reduction of risk by decay of short-lived radionuclides, protection of human health and the environment, remediation costs, size of the ERDF, worker safety, presence of ecological and cultural resources, the use of institutional controls, and long-term monitoring costs.

- Remove pipelines associated with the TSD units where contamination levels associated with the pipelines exceed remedial action goals (RAGs). Treat as necessary and dispose of waste in the ERDF or as appropriate.

Because approximately three-quarters of the 116-N-3 Trench did not receive radioactive effluent, an underlying assumption is that that part of the trench is clean. Therefore, an implicit goal of this project is to identify the location (near the first dam) beyond which the 116-N-3 Trench soils no longer exceed direct exposure and groundwater/river protection cleanup standards.

The project will also implement the closure of the 120-N-1, 120-N-2, and 100-N-58 sites as specified in the closure plan (Appendix B of DOE-RL [1998a]). Closure involves removing the liner in the 120-N-2 Surface Impoundment, removing the sampling shed and fencing that surround the sites, and removing the feed pipeline if it is found to be contaminated.

There will be no remediation excavation in the 120-N-1, 120-N-2, and 100-N-58 earthen basins for closure. However, the Hypalon liner, sampling shed, and perimeter fence will be demolished and removed. The demolished components will be disposed in an appropriate nonhazardous disposal facility or recycled as scrap, as appropriate, and will be characterized appropriately to this end.

The data presented in the closure plan (Appendix B of DOE-RL [1998a]) indicate that the vadose zone under the 120-N-1, 120-N-2, and 100-N-58 sites did not contain concentrations of metals that are distinguishable from background. The data used to lead to this conclusion were obtained from samples located in areas expected to record adverse impacts from the units. An exception is the lack of data from samples that may have been influenced by an overflow of the North Settling Pond. There are some indications that this event may have occurred and that standing water was present in the northern portion of the units. To evaluate any impacts from an event of this kind, two samples will be collected from the northern part of the units.

Tables 1-1, 1-2, and 1-3 identify the DQO scoping team members, the DQO workshop team members, and the key decision makers, respectively. The DQO scoping team developed the checklist and binder prior to beginning the seven-step DQO process. The DQO workshop team members participated in the seven-step process, and the key decision makers provided the external review of the results of the seven-step DQO process.

Table 1-1. DQO Scoping Team Members.

Name	Organization	Area of Expertise (Role)	Phone Number
B. Mukherjee	BHI Project Engineer	BHI Project Engineer	372-9218
C. W. Hedel	CHI Environmental Engineering	CHI Project Lead	372-9602
R. W. Ovink	CHI Regulatory Support and Environmental Sciences	DQO Facilitator	372-9631
J. D. Ludowise	CHI Environmental Engineering	Design Engineer	372-9324
J. W. Badden	CHI Regulatory Support and Environmental Sciences	Regulatory Analysis	372-9698
R. W. Jackson	BHI Field Services Waste Management	Waste Management	373-5473
S. K. DeMers	BHI RadCon Engineering	Radiation Control and Protection	531-0729
S. G. Weiss	CHI Regulatory Support and Environmental Sciences	Ecological Resources Protection	372-9531
W. J. Adam	CHI Safety and Health	Safety Analysis	372-9311
S. W. Clark	CHI Regulatory Support and Environmental Sciences	Risk Scenarios/Pathways	372-9613
J. J. Sharpe	CHI Regulatory Support and Environmental Sciences	Cultural Resource Protection	372-9369

BHI = Bechtel Hanford, Inc.
CHI = CH2M Hill Hanford, Inc.
RadCon = Radiological Control

Table 1-2. DQO Workshop Team Members. (2 pages)

Name	Organization	Area of Expertise (Role)	Phone Number
B. Mukherjee	BHI Project Engineer	BHI Project Engineer	372-9218
C. W. Hedel	CHI Environmental Engineering	CHI Project Lead	372-9602
R. W. Ovink	CHI Regulatory Support and Environmental Sciences	DQO Facilitator	372-9631
J. D. Ludowise	CHI Environmental Engineering	Design Engineer	372-9324
J. W. Badden	CHI Regulatory Support and Environmental Sciences	Regulatory Analysis	372-9698

Table 1-2. DQO Workshop Team Members. (2 pages)

Name	Organization	Area of Expertise (Role)	Phone Number
G. J. Borden	BHI Field Services Waste Management	Waste Management	373-1915
S. K. DeMers	BHI RadCon Engineering	Radiation Control and Protection	531-0729
S. G. Weiss	CHI Regulatory Support and Environmental Sciences	Ecological Resources Protection	372-9531
W. J. Adam	CHI Safety and Health	Safety Analysis	372-9311
S. W. Clark	CHI Regulatory Support and Environmental Sciences	Risk Scenarios/Pathways	372-9613
J. J. Sharpe	CHI Regulatory Support and Environmental Sciences	Cultural Resource Protection	372-9369
A. Antipas	CH2M Hill	Chemist	(425) 453-5005, ext. 5051
A. Turner	CH2M Hill	Statistician	(518) 756-1657
W. S. Thompson	BHI Site Assessments and Closeout	Sampling and Onsite Measurements Scientist	372-9597
S. Blackburn	SAIC	Statistician	372-7754

Table 1-3. DQO Key Decision Makers.

Name	Organization	Area of Expertise (Role)	Phone Number
G. I. Goldberg	RL Restoration Projects Division	Decision maker	376-9552
F. W. Bond	Washington State Department of Ecology	Decision maker	736-3037
D. A. Faulk	U. S. Environmental Protection Agency	Decision maker	376-8631

RL = U.S. Department of Energy, Richland Operations Office

Figure 1-2 contains a process diagram for the DQO scoping/workbook/conceptual site model development process. The DQO scoping/conceptual site model/DQO/sampling and analysis plan development process is depicted in the process diagram shown in Figure 1-3.

Figure 1-2. DQO Scoping/Workbook/Conceptual Site Model Development Process.

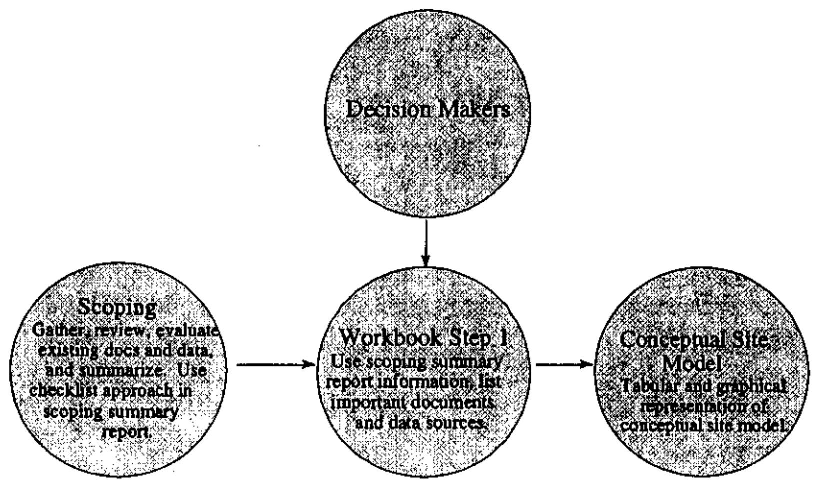
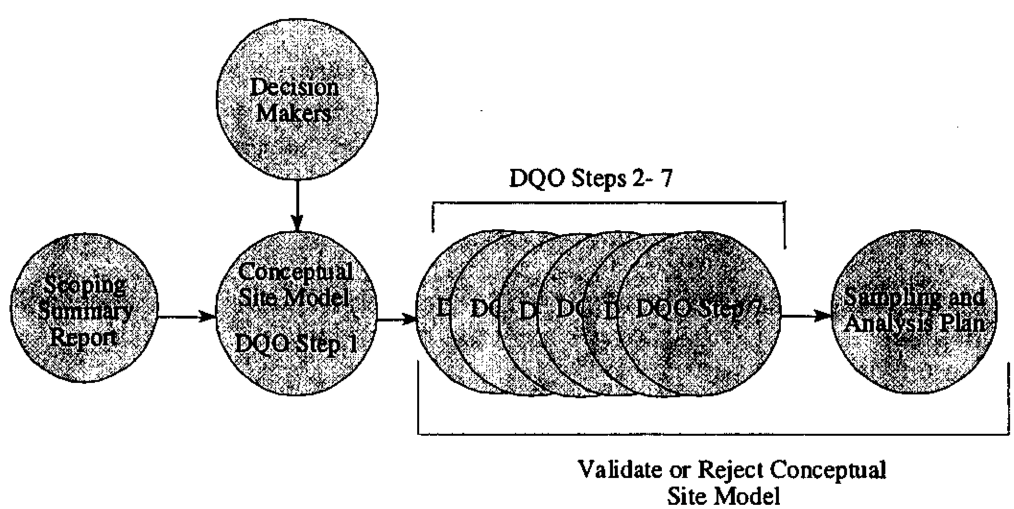


Figure 1-3. DQO Scoping/Conceptual Site Model/ DQO/SAP Development Process.



The documents listed in Table 1-4 were used to support the descriptions for the each of the TSD units for this project.

Table 1-4. Existing Documents and Data Sources.

Reference	Summary
Qualitative Risk Assessment for the 100-NR-1 Source Operable Unit, BHI-00054, Rev. 1 (BHI 1995a)	Identifies risks at some of the source waste sites in the 100-N Area that may warrant remedial action.
Qualitative Risk Assessment for the 100-NR-2 Operable Unit, BHI-00055, Rev. 1 (BHI 1995b)	Determined that some contaminant concentrations in groundwater exceed health-based risk levels.
Data Quality Objectives Workshop Results for 1301-N and 1325-N Characterization, BHI-00368, Rev. 0 (BHI 1996)	Presents DQOs for the limited field investigation characterization.
1301-N and 1325-N Liquid Waste Disposal Facilities Limited Field Investigation Report, DOE/RL-96-11, Rev. 0 (DOE-RL 1996)	The results of a study were used to determine if soil remediation was required to protect groundwater from a future potential impact and, if so, when remediation should be performed.
100-NR-1 Treatment, Storage, and Disposal Units Corrective Measures Study/Closure Plan, DOE/RL-96-39, Rev. 0 (DOE-RL 1998a)	Conducted to gather information to support selection of a remedial alternative to address contamination at the four 100-NR-1 TSD units and the two associated sites
Proposed Plan for Interim Remedial Action and Dangerous Waste Modified Closure of the Treatment, Storage, and Disposal Units and Associated Sites in the 100-NR-1 Operable Unit, DOE/RL-97-30, Rev. 0 (DOE-RL 1998b)	Presents the proposed plan for interim remedial action and dangerous waste modified closure of the sites.
100-NR-1 Treatment, Storage, and Disposal Units Engineering Study, BHI-01092, Rev. 1 (BHI 1999b)	Evaluated options for remediation of the 116-N-1 and 116-N-3 sites. Recommended alternative of boxing highly contaminated soil for disposal in the ERDF. Also recommended additional characterization to better define the nature and extent of contamination.
Environmental Restoration Disposal Facility Waste Acceptance Criteria, BHI-00139, Rev. 3 (BHI 1998a)	Identifies the criteria for accepting mixed waste at the ERDF.
Field Investigation Plan for 1301-N and 1325-N Facilities Sampling to Support Remedial Design, BHI-01236, Rev. 1 (BHI 1998b)	Sampling plan for characterization work identified in the engineering study (BHI 1999b).
Data Summary Report for 116-N-1 and 116-N-3 Facility Soil Sampling to Support Remedial Design, BHI-01271, Rev. 0 (BHI 1999c)	Presents the results of the characterization work performed under the field investigation plan (BHI 1998b). Concluded that extent of contamination is significantly less than was assumed in the engineering study (BHI 1999b).

Table 1-5 identifies the contaminants of potential concern (COPCs) that were identified in the CMS/closure plan (DOE-RL 1998a). The table lists the known or suspected sources of contamination, the type of contamination, a list of the COPCs, and the affected environmental media.

Ammonium hydroxide was added to the water used for reactor graphite and shield cooling to maintain a pH of approximately 10 and reactor control rod cooling to maintain a pH of approximately 7. The concentration of ammonium hydroxide was about 40 ppm in both cooling systems. Ammonium hydroxide is not listed in WAC 73-303-9903. The MTCA Method B formula value for ammonia (i.e., the same as ammonium hydroxide) is 2.72 X 10^6 ppm. No human health or environmental threats are posed by ammonium hydroxide at low concentrations (40 ppm), so it is not considered a COPC.

Morpholine was added to the water in the reactor secondary coolant loop to control pH between 8.6 and 9.2. The concentration of morpholine in the cooling water was about 4 ppm. Morpholine is not listed in WAC 173-303-9903 and it was not present in the cooling water in high enough concentration to be considered ignitable. There is no MTCA Method B formula value for morpholine. No human health or environmental threats are posed by morpholine at low concentrations (4 ppm), so it is not considered a COPC.

Hydrazine was added to the graphite and shield cooling water, reactor control rod cooling water, and the reactor secondary cooling water to scavenge oxygen and thereby reduce corrosion. The concentration of hydrazine in the cooling water was 0.04, 0.15 and 1 ppm in the graphite and shield cooling water, reactor control rod cooling water, and the reactor secondary cooling water, respectively. Hydrazine is listed in WAC 173-303-9903 (code U133). However, the discharge of hydrazine involved a release of material that was in use within the process and is not designated as a discarded commercial product; therefore, hydrazine is not designated as a dangerous waste. The MTCA Method B formula value for hydrazine in soils is 0.33 ppm. Hydrazine was used in very low concentrations and is a powerful reducing agent so it would decompose upon contact with naturally occurring organic materials and metallic oxides that are present in the soils. No human health or environmental threats are posed by hydrazine, so it is not considered a COPC.

Methanol is a dangerous waste reported in the RCRA dangerous waste permit application for the 116-N-1 and 116-N-3 sites. Methanol was used at the 100-N laboratories and may have been disposed in the laboratory floor drains that emptied into the 116-N-1 and 116-N-3 sites. Methanol is regulated as a "F003" waste because of its characteristic of ignitability. Under 40 CFR 261.3(a)(2)(iii), wastes listed solely due to a characteristic are no longer listed when a waste mixture no longer exhibits the characteristic. Methanol would have been diluted with large amounts of water, so the concentration of methanol in water disposed to the 116-N-1 and 116-N-3 sites would have been very low (less than 30 ppm). At this concentration, methanol would not be ignitable.

Unlike the Federal regulations, the Washington State dangerous regulations do not allow for removal of listed waste codes in situations where the listing is based solely on characteristics and a waste mixture does not exhibit the characteristic. As a consequence, the "state-only" listed waste code can be assigned. However, Ecology has acknowledged that Federal land disposal restrictions do not apply to state-only listed waste. The 100-NR-1 CERCLA ROD acknowledges the state-only listed "F003" waste code associated with wastes arising from remedial actions at the cribs/trenches, and states that "...it is anticipated that these F003 wastes will meet ERDF waste acceptance criteria without the need for treatment due to very low concentrations of methanol." Therefore, methanol is not a COPC for purposes of waste disposal.

Methanol readily biodegrades and is not expected to be present in measurable concentrations. The MTCA Method B formula value for methanol in soil is 4,000 ppm. No human health or environmental threats are posed by methanol, so it is not considered a COPC for the purposes of site cleanup.

An underlying assumption of this DQO process is that any contamination from past releases at any sites that are not identified in the CMS (DOE-RL 1998a) is not within the scope of the remedial action and is, therefore, not within the scope of this DQO process.

Table 1-5. Sources of Contamination, COPCs, and Affected Media (from DOE-RL 1998a). (3 pages)

WS	[illegible] (Process Waste Stream)	Type of Contamination from Waste Stream [illegible]	COPCs (Specific Contaminants)	[illegible]
1	116-N-1 Crib, UPR-100-N-31, and associated pipelines	Radionuclides	Americium-241 Cesium-137 Cobalt-60 Europium-154 Europium-155 Nickel-63 Plutonium-239/240 Strontium-90 Thorium-232 Tritium Uranium-233/234 Uranium-238	Surface (0 to 4.6 m [0 to 15 ft] bgs) soil, concrete structures, and pipelines
			Americium-241 Cesium-137 Cobalt-60 Europium-154 Europium-155 Nickel-63 Plutonium-239/240 Strontium-90 Thorium-232 Tritium Uranium-233/234 Uranium-238	Subsurface (>4.6 m [>15 ft] bgs) soil
		Inorganics	Cadmium Chromium (total) Chromium (VI) Lead Mercury Nitrate	Surface (0 to 4.6 m [0 to 15 ft] bgs) soil, concrete structures, and pipelines
			Cadmium Chromium (total) Chromium (VI) Lead Mercury Nitrate	Subsurface (>4.6 m [>15 ft] bgs) soil

Table 1-5. Sources of Contamination, COPCs, and Affected Media (from DOE-RL 1998a). (3 pages)

WS #	Known or Suspected Source of Contamination (Process/Waste Stream)	Type of Contamination from Each Source (General Contamination)	COPCs (Specific Contamination)	Affected Media
2	116-N-1 Trench and cover panels	Radionuclides	Americium-241 Cesium-137 Cobalt-60 Europium-154 Europium-155 Nickel-63 Plutonium-239/240 Strontium-90 Thorium-232 Tritium Uranium-233/234 Uranium-238	Subsurface (>4.6 m [>15 ft] bgs) soil and concrete structures
		Inorganics	Cadmium Chromium (total) Chromium (VI) Lead Mercury Nitrate	Subsurface (>4.6 m [>15 ft] bgs) soil and concrete structures
3	116-N-3 Crib, Trench, cover panels, and associated pipelines	Radionuclides	Americium-241 Cesium-137 Cobalt-60 Europium-154 Europium-155 Nickel-63 Plutonium-239/240 Strontium-90 Thorium-228 Thorium-232 Tritium Uranium-233/234 Uranium-238	Subsurface (>4.6 m [>15 ft] bgs) soil, concrete structures, and pipelines
		Inorganics	Cadmium Lead Mercury Nitrate	Subsurface (>4.6 m [>15 ft] bgs) soil, concrete structures, and pipelines

Table 1-5. Sources of Contamination, COPCs, and Affected Media (from DOE-RL 1998a). (3 pages)

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4	120-N-1, 120-N-2, 100-N-58, and associated pipelines	Radionuclides	None (see Table 2-15 of the CMS [DOE-RL 1998a])	Surface (0 to 4.6 m [0 to 15 ft] bgs) soil, concrete structures, and pipelines
		Inorganics	Antimony Arsenic Barium Beryllium Cadmium Chromium (total) Chromium (VI) Copper Lead Manganese Mercury Nickel Selenium Silver Sulfate Thallium Vanadium Zinc pH	Northern part of the units, surface (0 to 4.6 m [0 to 15 ft] bgs) soil (see page B-26 of the CMS [DOE-RL 1998a])

[a] Remediation projects refer to the "process (P)"; decontamination and decommissioning projects or projects with multiple sources of contamination refer to the "waste stream (WS)."
[b] Except for americium-241 and nickel-63, COPCs are taken from the CMS/closure plan (DOE-RL 1998a). Americium-241 was added to the list because it is an alpha particle emitter and is generally present whenever plutonium from weapons production is present. Nickel-63 was added because it is an activation product that has been frequently observed in other 100 Area remediation projects.
bgs = below ground surface

Table 1-6 identifies the list of COPCs that were excluded from the investigation and the rationale for their exclusion.

Table 1-6. COPC Exclusions and Justifications. (2 pages)

WS	[illegible]	[illegible]	[illegible]
1 – 116-N-1 Crib, UPR-100-N-31, and associated pipelines	Thorium-232 Uranium-233/234 Uranium-238 Cadmium Chromium (total) Chromium (VI) Lead	Surface (0 to 4.6 m [0 to 15 ft] bgs) soil, concrete structures, and pipelines	Contaminant concentrations are less than PRGs. See Chapter 4.0 of the CMS (DOE-RL 1998a).

Table 1-6. COPC Exclusions and Justifications. (2 pages)

WS#	COPCs Excluded	Media	Rationale for Exclusion
	Cesium-137 Cobalt-60 Europium-154 Europium-155 Thorium-232 Uranium-233/234 Uranium-238 Cadmium Lead Mercury	Subsurface (>4.6 m [>15 ft] bgs) soil	Contaminant concentrations are less than PRGs. See Chapter 4.0 of the CMS (DOE-RL 1998a). However, cesium-137 is not excluded from the deep zone because it is found in the groundwater underlying the sites.
2 – 116-N-1 Trench and cover panels	Cesium-137 Cobalt-60 Europium-154 Europium-155 Thorium-232 Uranium-233/234 Uranium-238 Cadmium Lead Mercury	Subsurface (>4.6 m [>15 ft] bgs) soil and concrete structures	Contaminant concentrations are less than PRGs. See Chapter 4.0 of the CMS (DOE-RL 1998a). However, cesium-137 is not excluded from the deep zone because it is found in the groundwater underlying the sites.
3 – 116-N-3 Crib and Trench, cover panels, and associated pipelines	Cesium-137 Cobalt-60 Europium-154 Europium-155 Thorium-228 Thorium-232 Uranium-233/234 Uranium-238 Cadmium Lead Mercury	Subsurface (>4.6 m [>15 ft] bgs) soil, concrete structures, and pipelines	Contaminant concentrations are less than PRGs. See Chapter 4.0 of the CMS (DOE-RL 1998a). However, cesium-137 is not excluded from the deep zone because it is found in the groundwater underlying the sites.
4 – 120-N-1, 120-N-2, 100-N-58, and associated pipelines	None	0 to 4.6 m [0 to 15 ft] bgs) soil, concrete structures, and pipelines	No radiochemical COPCs identified at these sites; all nonradiochemical COPCs are retained. See page B-26 of the CMS (DOE-RL 1998a).

PRG = preliminary remediation goal

A final list of contaminants of concern (COCs) and the rationale for their inclusion are provided in Table 1-7.

Table 1-7. Final COC List. (2 pages)

[illegible]	[illegible]	[illegible]	[illegible]
Radioactive Constituents			
1 – 116-N-1 Crib, UPR-100-N-31, and associated pipelines 2 – 116-N-1 Trench and cover panels 3 – 116-N-3 Crib and Trench, cover panels, and associated pipelines	Americium-241 Cesium-137 Cobalt-60 Europium-154 Europium-155 Nickel-63 Plutonium-239/240 Strontium-90 Tritium	Surface (0 to 4.6 m [0 to 15 ft] bgs) soil, concrete structures, and pipelines	Contaminant concentrations exceed PRGs. See interim remedial action ROD (Ecology et al. 2000). Americium-241 is retained because it is an alpha particle emitter associated with plutonium from weapons production. Nickel-63 is added because it is a common activation product and has been found in other 100 Area sites. Strontium-90 is added in the deep zone because it is found in the groundwater underlying the sites.
	Americium-241 Nickel-63 Plutonium-239/240 Strontium-90 Tritium	Subsurface (>4.6 m [>15 ft] bgs) soil	
4 – 120-N-1, 120-N-2, 100-N-58, and associated pipelines	None	Surface (0 to 4.6 m [0 to 15 ft] bgs) soil, concrete structures, and pipelines	No radioactive contaminants of concern identified in the CMS (DOE-RL 1998a).
For purposes of waste characterization, all radioactive sites	Americium-241 Cesium-137 Cobalt-60 Europium-154 Europium-155 Nickel-63 Plutonium-239/240 Strontium-90 Tritium	Soil, concrete structures, and pipelines	Necessary for waste characterization.
Chemical Constituents			
1 – 116-N-1 Crib, UPR-100-N-31, and associated pipelines 2 – 116-N-1 Trench and cover panels	Nitrate Mercury	Surface (0 to 4.6 m [0 to 15 ft] bgs) soil, concrete structures, and pipelines	Contaminant concentrations exceed PRGs. See interim remedial action ROD (Ecology et al. 2000).
	Chromium (total) Chromium (VI) Nitrate	Subsurface (>4.6 m [>15 ft] bgs) soil and concrete structures	
3 – 116-N-3 Crib and Trench, cover panels, and associated pipelines	Nitrate Mercury	Surface (0 to 4.6 m [0 to 15 ft] bgs) soil, concrete structures, and pipelines	
	Nitrate	Subsurface (>4,6 m [>15 ft bgs]) soil, concrete structures, and pipelines	

Table 1-7. Final COC List. (2 pages)

WS	COC	Media	Rationale for Inclusion
4 – 120-N-1, 120-N-2, 100-N-58, and associated pipelines	Antimony Arsenic Barium Beryllium Cadmium Chromium (total) Chromium (VI) Copper Lead Manganese Mercury Nickel Selenium Silver Sulfate Thallium pH Vanadium Zinc	Surface (0 to 4.6 m [0 to 15 ft] bgs) soil	See page B-26 of the CMS (DOE-RL 1998a).

Table 1-8 identifies all COC migration pathways. These migration pathways are taken from the CMS (DOE-RL 1998a).

Table 1-8. COC Exposure and Migration Pathways (from DOE-RL 1998a). (2 pages)

WS	COCs	Media	Exposure/Migration Pathways
1 – 116-N-1 Crib, UPR-100-N-3, and associated pipelines	Americium-241 Cesium-137 Cobalt-60 Europium-154 Europium-155 Nickel-63 Plutonium-239/240 Strontium-90 Tritium	Surface (0 to 4.6 m [0 to 15 ft] bgs) soil, concrete structures, and pipelines	Ingestion, inhalation, and external exposure; migration to groundwater and the Columbia River.
	Nitrate Mercury	Surface (0 to 4.6 m [0 to 15 ft] bgs) soil, concrete structures, and pipelines	Ingestion; migration to groundwater and the Columbia River.
	Americium-241 Tritium Nickel-63 Plutonium-239/240 Strontium-90	Subsurface (>4,6 m [>15 ft] bgs) soil	Migration to groundwater and the Columbia River.
	Chromium Nitrate	Subsurface (>4.6 m [>15 ft] bgs) soil	Migration to groundwater and the Columbia River.

Table 1-8. COC Exposure and Migration Pathways (from DOE-RL 1998a). (2 pages)

AWS	COCs	Media	Exposure/Migration Pathway
2 – 116-N-1 Trench and cover panels	Americium-241 Tritium Nickel-63 Plutonium-239/240 Strontium-90	Subsurface (>4.6 m [>15 ft] bgs) soil and concrete structures	Migration to groundwater and the Columbia River.
	Chromium Nitrate	Subsurface (>4.6 m [>15 ft] bgs) soil and concrete structures	Migration to groundwater and the Columbia River.
3 – 116-N-3 Crib, Trench, cover panels, and associated pipelines	Americium-241 Tritium Nickel-63 Plutonium-239/240 Strontium-90	Subsurface (>4.6 m [>15 ft] bgs) soil, concrete structures, and pipelines	Migration to groundwater and the Columbia River.
	Nitrate	Subsurface (>4.6 m [>15 ft] bgs) soil, concrete structures, and pipelines	Migration to groundwater and the Columbia River.
4 – 120-N-1, 120-N-2, 100-N-58, and associated pipelines	Antimony Arsenic Barium Beryllium Cadmium Chromium Copper Lead Manganese Mercury Nickel Selenium Silver Thallium Sulfate pH Vanadium Zinc	Surface (0 to 4.6 m [0 to 15 ft] bgs) soil, concrete structures, and pipelines	Migration to groundwater and the Columbia River.

The potential human and environmental receptors are identified in Table 1-9. The potential human and environmental receptors are taken from the CMS (DOE-RL 1998a).

Table 1-9. Human and Environmental Receptors (from DOE-RL 1998a).

WSG	COCs	Media	Human Receptors (from Section 3.4 in the CMS [DOE-RL 1998a])	Ecological Receptors (from Section 3.4 in the CMS [DOE-RL 1998a])
1 – 116-N-1 Crib, UPR-100-N-3, and associated pipelines	Americium-241 Cesium-137 Cobalt-60 Europium-154 Europium-155 Nickel-63 Plutonium-239/240 Strontium-90 Tritium Nitrate Mercury	Surface (0 to 4.6 m [0 to 15 ft] bgs) soil, concrete structures, and pipelines	Current worker, future worker, occasional user, and future resident	Terrestrial
	Americium-241 Tritium Nickel-63 Plutonium-239/240 Strontium-90 Chromium Nitrate	Subsurface (>4.6 m [>15 ft] bgs) soil	None	Aquatic, riparian
2 – 116-N-1 Trench and cover panels	Americium-241 Tritium Nickel-63 Plutonium-239/240 Strontium-90 Chromium Nitrate	Subsurface (>4.6 m [>15 ft] bgs) soil and concrete structures	None	Aquatic, riparian
3 – 116-N-3 Crib, Trench, cover panels, and associated pipelines	Americium-241 Tritium Nickel-63 Plutonium-239/240 Strontium-90 Nitrate	Subsurface (>4.6 m [>15 ft] bgs) soil, concrete structures, and pipelines	None	Aquatic, riparian
4 – 120-N-1, 120-N-2, 100-N-58, and associated pipelines	Antimony Arsenic Barium Beryllium Cadmium Chromium Copper Lead Manganese Mercury Nickel Nitrate Selenium Silver Thallium Sulfate pH Vanadium Zinc	Surface (0 to 4.6 m [0 to 15 ft] bgs) soil, concrete structures, and pipelines	Current worker, future worker, occasional user, and future resident	Aquatic, riparian

The current and potential future land uses of the site are identified in Table 1-10.

Table 1-10. Current and Potential Future Site Land Use.

[illegible]	[illegible]
Industrial	Preservation, conservation, and recreation[a]

[a] Future land uses are identified in the *Final Hanford Comprehensive Land-Use Plan Environmental Impact Statement* (DOE 1999). While none of the proposed future land uses include residences, a rural-residential exposure scenario is being assumed to calculate cleanup levels as specified in the interim remedial action ROD (Ecology et al. 2000).

Table 1-11 lists the preliminary applicable or relevant and appropriate requirements (ARARs) and preliminary remediation goals (PRGs) for the TSD units.

Table 1-11. List of Preliminary ARARs and PRGs. (2 pages)

[illegible]	[illegible]	[illegible]	[illegible]
[illegible]			
Americium-241	Draft EPA standard of 15 mrem/yr above background for protection of human health (40 CFR 196). Concentrations represent the 15 mrem/yr limit for each radionuclide alone. MCLs promulgated under the Federal *Safe Drinking Water Act* (40 CFR 141) that correspond to 4 mrem/yr. Concentrations represent the 4 mrem/yr limit for each radionuclide alone.	41.6[b]	[c]
Cesium-137		6.1	[c]
Cobalt-60		1.4	[c]
Europium-154		3.1	[c]
Europium-155		127	[c]
Nickel-63		4,031[b]	[c]
Plutonium-239/240		23.5	[c]
Strontium-90		3.7	[c]
Tritium		241	2,000
[illegible]			
Antimony	MTCA Non-zero MCL goals and MCL promulgated under the Federal *Safe Drinking Water Act* (40 CFR 141) and/or the State of Washington (WAC 246-290). Ambient water quality criteria developed under the Federal *Clean Water Act* (Section 304) or standards promulgated by the State of Washington (WAC 173-201).	32	---
Arsenic		20[d]	20[d]
Barium		5,600	[c]
Beryllium		400	---
Cadmium		80	[c]
Chromium (III)		80,000	[c]
Chromium (VI)		400	2
Copper		2,960	---
Lead		353[e]	[c]
Manganese		11,200	---
Mercury		24	[c]
Nickel		1,600	---
Nitrate		113,000	4,400
Selenium		400	[c]

Table 1-11. List of Preliminary ARARs and PRGs. (2 pages)

COCs	Preliminary ARARs	PRGs	
		Soils 0 to 4.6 m (0 to 15 ft) bgs for Surface Exposure	Subsurface Soils >4.6 m (>15 ft) bgs for Groundwater/River Protection
Silver		400	[c]
Sulfate		N/A	25,000
Thallium		6	---
pH (pH units)		<2 or >12.5	<2 or >12.5
Vanadium		560	---
Zinc		24,000	---
Organics (mg/kg)			
None	---	---	---

[a] Where regulations (ARARs) differ, the value listed is from the more restrictive regulation.
[b] Except for americium-241 and nickel-63, radionuclide values are from Table 2 of the interim remedial action ROD (EPA et al. 2000) and represent the single radionuclide soil concentration corresponding to a 15 mrem/yr dose. Values for americium-241 and nickel-63 were calculated using the RESidual RADioactivity dose model (RESRAD), Version 5.91 (ANL 1993).
[c] The RESRAD unit gradient model predicts that the contaminant will not reach groundwater within 1,000-year time frame.
[d] Arsenic limits are from MTCA Method A due to high background values per discussions with regulators.
[e] A MTCA Method B value for lead is not available. This value is based on EPA's *Integrated Exposure Uptake Biokinetic Model for Lead in Children* (EPA 1994a).
CFR = *Code of Federal Regulations*
EPA = U.S. Environmental Protection Agency
MCL = maximum contaminant level
N/A = not applicable

The potential exposure scenarios for the TSD units are identified in Table 1-12.

Table 1-12. Exposure Scenarios.

Scenario	Exposure Scenario Description (from Section 3.3.4 of CMS (DOE-RL 1996a))
Rural-residential	Human receptor -- Ingestion of contaminated soils, external dose from soils, inhalation of contaminated dust, and ingestion of contaminated plants and animals. Ecological receptor -- Ingestion of contaminated soils, water, and food; external dose from soils; inhalation of contaminated dust; and uptake of contaminants through gill structure or other permeable organs.

Table 1-13 provides information on the tabular site conceptual model.

Table 1-13. Tabular Site Conceptual Model. (2 pages)

[illegible]	Primary Source	Primary Release Mechanism	Secondary Source	Secondary Release Mechanism	Migration Pathway	Receptors
Am-241	Fuel element	Rupture	116-N-1/ 116-N-3 Crib/Trench sediments	Resuspension, deposition, biotic uptake, infiltration/ percolation, leaching, radiation, excavation/ direct contact	Ingestion, dermal contact, inhalation, external radiation	Current worker, future worker, occasional user, future resident, terrestrial species, aquatic species, riparian species
Cs-137	Fuel element	Rupture				
Co-60	Activation product	Activation of materials surrounding reactor fuel				
Eu-154	Fuel element	Rupture				
Eu-155	Fuel element	Rupture				
Ni-63	Activation product	Activation of nickel in steel and stainless steel				
Pu-239/240	Fuel element	Rupture				
Sr-90	Fuel element	Rupture				
Tritium	Activation product	Activation of cooling water				
Nitrate	Reactor decontamination	Flushing of decontamination solution		Resuspension, deposition, biotic uptake, infiltration/ percolation, leaching, excavation/ direct contact	Ingestion, dermal contact, inhalation	Current worker, future worker, occasional user, future resident, terrestrial species, aquatic species, riparian species
Mercury	Instruments	Breakage				
Chromium	Reactor decontamination/anti-corrosion	Flushing of decontamination solution				

Table 1-13. Tabular Site Conceptual Model. (2 pages)

COPCs	Primary Source	Primary Release Mechanism	Secondary Source	Secondary Release Mechanism	Exposure Pathways	Receptors
Antimony Arsenic Barium Beryllium Cadmium Chromium Copper Lead Manganese Mercury Nickel Nitrate Selenium Silver Thallium Sulfate Vanadium Zinc pH	Water treatment	Process backflushes, ion exchange, regeneration waste, etc.	120-N-1, 120-N-2, and 100-N-58 sediments	Resuspension, deposition, biotic uptake, infiltration/ percolation, leaching, excavation/ direct contact	Ingestion, dermal contact, inhalation	Current worker, future worker, occasional user, future resident, terrestrial species, aquatic species, riparian species

Figure 1-4 provides a graphic of the conceptual site model.

Figure 1-4. Graphical Description of the Conceptual Site Model (from DOE-RL 1998a).

Exposure		*Human Receptors*			
		Radionuclides		*Nonradionuclides*	
Media	Route	*Rural Residential*	*MCRIS**	*Rural Residential*	*MCRIS**
Soils	Ingestion	●	●	●	●
	Dermal	—	—	—	—
	External	●	●	NA	NA
Air (Dust)	Inhalation	●	●	—	—
	External	—	—	NA	NA
Groundwater	Ingestion	—	—	—	—
	Inhalation	—	—	—	—
	Dermal	—	—	—	—
	External	—	—	NA	NA
Surface Water	Ingestion	—	—	—	—
	Inhalation	—	—	—	—
	Dermal	—	—	—	—
	External	—	—	NA	NA
Biota	Dairy	I	—	—	—
	Beef	I	—	—	—
	Game	I	—	—	—
	Fish	I	—	—	—
	Plant/Crop	I	—	NA	NA

SOURCE: DOE-RL, 1993a

* Modified CRCIA Ranger/Industrial Scenario

NA = Not Applicable

E9606093.1

● Primary Pathway

I Indirect Pathway

— Pathway Not Assessed

Table 1-14 specifies the regulatory and project constraints in relation to regulatory milestones.

Table 1-14. Regulatory Milestones.

Milestone	Due Date	Regulatory Driver
Begin remediation for 100-NR-1 TSD sites	July 2000	RCRA Sitewide permit requires that remediation for 100-NR-1 TSD sites begin not later than July 2000 and completion not later than June 2003.
Begin closure activities for 120-N-1, 120-N-2, 100-N-58, and associated pipelines	July 2001	
Complete remediation for 100-NR-1 TSD sites	June 2003	

The project milestones and regulatory drivers for this DQO process are specified in Table 1-15.

Table 1-15. Project Milestones.

Milestone	Due Date	Regulatory Driver
DQO workbook	January 2000	None
Sampling and analysis plan	March 2000	None
Field implementation	July 2000	RCRA Sitewide permit
Laboratory analyses	July 2000, through June 2003	RCRA Sitewide permit requires that remediation for 100-NR-1 TSD sites begin not later than July 2000 and completion not later than June 2003.
Data quality assessment	TBD	None
Closeout report	TBD	June 2003

TBD = to be determined

Table 1-16 provides a breakdown of cost in respect to the project budget.

Table 1-16. Project Budget.

Project Milestones	Budget
DQO workbook development	$89.4K
Sampling and analysis plan development	$46.3K
Field implementation	TBD; remediation is in the design phase, and cost estimating and budgeting will be developed at completion of design.
Laboratory analyses	TBD; remediation is in the design phase, and cost estimating and budgeting will be developed at completion of design.
Data quality assessment	N/A; will be prepared as part of site closeout effort following site remediation.
Documentation of investigation results	TBD; remediation is in the design phase, and cost estimating and budgeting will be developed at completion of design.

N/A = not applicable
TBD = to be determined

As stated above, the purpose of the project is to remediate the sites identified in the interim remedial action ROD for the 100-NR-1 TSD sites (Ecology et al. 2000). The statements in Table 1-17 are in alignment with that purpose. Additionally, a requirement of the project is to characterize the waste for disposal.

Table 1-17. Concise Statement of the Problem. (2 pages)

- Given the goal of removing soils, structures, pipelines, etc., in accordance with the interim remedial action ROD (Ecology et al. 2000) that exceed direct exposure RAOs for rural-residential exposure to a depth of 4.6 m (15 ft) below surrounding grade or to the bottom of the engineered structure (whichever is deeper), the problem is to verify that the sites meet the RAOs for rural-residential exposure of 15 mrem/yr above natural background for radionuclides and MTCA Method B values for nonradioactive contaminants.
- Given the goal of removing soils, structures, pipelines, etc., in accordance with the interim remedial action ROD to a depth of 1.5 m (5 ft) below the engineered structures of 116-N-1 and 116-N-3 units that contain plutonium-239/240 contaminants, the problem is to verify that the cleanup standards for the protection of groundwater and the Columbia River have been met for remaining soils.
- Given the goal of using overburden and layback as part of the backfill in accordance with the interim remedial action ROD, the problem is to verify that crib/trench cover contamination does not exceed the goals for rural-residential exposure and/or for protection of the Columbia River.
- Given the goal of waste characterization, the problem is to verify that radioactive and chemical constituents in the waste are compliant with the waste acceptance requirements of the facility receiving the waste.

Table 1-17. Concise Statement of the Problem. (2 pages)

- Given the goal of determining where the uncontaminated portion of the 116-N-3 Trench ends, the problem is to identify a transition zone near the first dam that meets the conditions for direct exposure and river protection without excavation (and, thereby, establish that the remainder of the 116-N-3 Trench, downstream of that transition zone, is clean).
- Given the goal of removing the liner, the pipelines (if contaminated), fence, and sampling shed at the nonradioactive sites (i.e., 120-N-1, 120-N-2, and 100-N-58), the problem is to determine if the debris meets disposal criteria.

2.0 STEP 2 -- IDENTIFY THE DECISION

2.1 PURPOSE

The purpose of DQO Step 2 is to define the principal study questions (PSQs) to be resolved using new or existing measurements. Alternative actions are identified that could result from resolution of the PSQs, and the consequences of each of the alternative actions are evaluated in this step.

The PSQs and alternative actions are combined into decision statements that state the problem and associated alternative actions. DQO Step 2 is the key step from which DQO Steps 3 through 7 shall be based; therefore, it is critical that the decision statements developed are accurate and address all of the questions needing to be resolved and support all actions that may be taken.

2.1.1 Identify the Decision

Table 2-1 identifies the PSQs that will require environmental measurements (e.g., physical, chemical, or radiological data) to resolve.

Table 2-1. Principal Study Questions.

PSQ #	Principal Study Questions
1	Do excavated contaminated soil/debris/pipelines meet ERDF waste acceptance criteria?
2	Does debris/piping from nonradioactive sites (120-N-1, 120-N-2, and 100-N-58) meet requirements for disposal in onsite inert/demolition waste landfills?
3	Do soils remaining after remediation meet site cleanup criteria identified in the interim remedial action ROD or CMS/closure plan?
4	Do overburden and layback soils meet criteria for use as backfill?
5	Does imported soil from onsite borrow pits meet criteria for use as backfill?
6	Do pipelines from nonradioactive sites (120-N-1, 120-N-2, and 100-N-58) meet criteria for being left in place?
7	Where is the location in the 116-N-3 Trench (near the first dam) beyond which the soil and structure are clean and no remedial action is needed?

Table 2-2 identifies the alternative actions that could be taken after the PSQs have been resolved.

Table 2-2. Alternative Actions.

PSQ	AA	Alternative Actions
1	1	Excavated contaminated soil/debris meets ERDF waste acceptance criteria and is disposed in the ERDF.
	2	Excavated contaminated soil/debris exceeds ERDF waste acceptance criteria and cannot be disposed in the ERDF, and alternative disposal options need to be evaluated.
2	1	Debris meets criteria for disposal in onsite inert/demolition waste landfills and is disposed in onsite inert/demolition landfills.
	2	Debris exceeds criteria for disposal in onsite inert/demolition waste landfills and is not disposed in onsite inert/demolition landfills.
3	1	Soils meet criteria for protection of groundwater and direct exposure as specified in the interim remedial action ROD or CMS/closure plan and remediation efforts are ended.
	2	Soils exceed criteria for protection of groundwater and direct exposure as specified in the interim remedial action ROD or CMS/closure plan and remediation efforts are continued.
4	1	Overburden and layback soil meet criteria for protection of groundwater and direct exposure as specified in the interim remedial action ROD and are used as backfill.
	2	Overburden and layback soil exceed criteria for protection of groundwater and direct exposure as specified in the interim remedial action ROD and are disposed of as contaminated waste.
5	1	Imported soil from onsite borrow pits meets criteria for use as backfill and is used for backfill.
	2	Imported soil from onsite borrow pits exceeds criteria for use as backfill and is not used for backfill.
6	1	Pipelines meet the requirements established in the CMS/closure plan for clean sites and are left in place.
	2	Pipelines exceed the requirements established in the CMS/closure plan for clean sites and are removed.
7	1	A transition zone near the first dam is identified beyond which remedial action (excavation of contaminated soil) is not needed.
	2	A transition zone near the first dam is identified beyond which additional remedial action (excavation of contaminated soil) is needed.

AA = alternative action

The potential consequences of erroneous alternative actions are listed in Table 2-3.

Table 2-3. Consequences of Erroneous Alternative Actions. (3 pages)

[illegible]	[illegible]	Consequences	Severity (Severe/ Not Severe)	[illegible]
1	1	Excavated contaminated soil/debris is erroneously determined to meet the ERDF waste acceptance criteria and soil/debris that exceeds ERDF waste acceptance criteria and is disposed in the ERDF.	Moderate	The ERDF is an engineered facility with features that are protective of groundwater and direct exposure.
	2	Excavated contaminated soil/debris is erroneously determined to exceed the ERDF waste acceptance criteria and alternative disposal options are evaluated for ERDF-acceptable soil/debris.	Low	There would be an economic impact, but the action would not pose a threat to human health or the environment.
2	1	Debris from nonradioactive sites is erroneously determined to meet dangerous waste requirements and contaminated debris is disposed in an onsite inert/demolition waste landfill.	Moderate	Inert demolition landfills are fairly remote and do not pose an immediate threat to human health or the environment.
	2	Debris from nonradioactive sites is erroneously determined to exceed dangerous waste requirements and alternative disposal options are evaluated to dispose of clean debris.	Low	There would be an economic impact, but the action would not pose a threat to human health or the environment.
3	1	Residual site contamination levels are erroneously determined to meet acceptable limits and remediation efforts are ended, leaving unacceptable levels of contamination at the site.	Severe	Residual levels of contamination could pose a risk to human health or the environment.
	2	Residual site contamination levels are erroneously determined to exceed acceptable limits and remediation efforts continue to cleanup an already clean site.	Low	There would be an economic impact, but the action would not pose a threat to human health or the environment.

Table 2-3. Consequences of Erroneous Alternative Actions. (3 pages)

PSQ #	AA #	Consequences	Severity (Severe/ Not Severe)	Rationale for Determining Consequence Severity
4	1	Contamination levels of overburden and layback soil are erroneously determined to be within limits acceptable for use as backfill, and contaminated overburden and layback soil are used as backfill.	Severe	Residual levels of contamination could pose a risk to human health or the environment.
	2	Contamination levels of overburden and layback soil are erroneously determined to exceed limits acceptable for use as backfill and clean overburden, and layback soil are disposed of as contaminated waste.	Low	There would be an economic impact, but the action would not pose a threat to human health or the environment.
5	1	Imported soil from onsite borrow pits is erroneously determined to meet limits acceptable for use as backfill and the site is backfilled with contaminated soil.	Low	Process history of borrow pits is such that even if contamination is present, it would be at very low levels and would not pose a significant threat to human health or the environment.
	2	Imported soil from onsite borrow pits is erroneously determined to exceed limits acceptable for use as backfill and the site is backfilled with clean soil from alternative sources.	Low	There would be an economic impact, but the action would not pose a threat to human health or the environment.
6	1	Contamination levels of pipelines associated with the 120-N-1, 120-N-2, and 100-N-58 sites are erroneously determined to meet criteria for the pipelines to be left in place, and contaminated pipelines are left in place.	Low	Contaminants of concern are such that even if some contamination is left in place, the consequences to human health and the environment are not significant.
	2	Contamination levels of pipelines associated with the 120-N-1, 120-N-2, and 100-N-58 sites are erroneously determined to exceed criteria for the pipelines to be left in place, and clean pipelines are excavated and disposed of in a landfill.	Low	There would be an economic impact, but the action would not pose a threat to human health or the environment.

Table 2-3. Consequences of Erroneous Alternative Actions. (3 pages)

PSQ #	AA #	Consequences	[illegible]	[illegible] Consequence Severity
7	1	Contamination levels in a transition zone near the first dam are erroneously determined to meet acceptable limits and no remediation actions are taken beyond this transition zone, leaving unacceptable levels of contamination at the site.	Severe	Residual levels of contamination could pose a risk to human health or the environment.
	2	Contamination levels in a transition zone near the first dam are erroneously determined to exceed acceptable limits, and remediation actions are taken beyond this transition zone to cleanup an already clean site.	Low	There would be an economic impact, but the action would not pose a threat to human health or the environment.

The PSQs and alternative actions are turned into decision statements in Table 2-4 using the following format: *Determine whether or not [unknown environmental conditions/issues/criteria from the PSQ] require (or support) [taking alternative actions].*

Table 2-4. Decision Statements. (2 pages)

DS #	Decision Statements
1	Determine if excavated contaminated soil/debris from radioactive sites (116-N-1, 116-N-3, and UPR-100-N-31) meets ERDF waste acceptance criteria (BHI 1998a) and can be disposed in the ERDF or if alternate disposal options need to be considered.
2	Determine if debris from nonradioactive sites (120-N-1, 120-N-2, and 100-N-58) meets requirements for disposal in onsite inert/demolition waste landfills or if alternate disposal options need to be considered.
3	Determine if soils remaining after remediation exceed site cleanup criteria identified in the interim remedial action ROD or CMS/closure plan and require additional remediation or if remedial action is complete.
4	Determine if contamination levels of overburden and layback soil exceed site criteria identified in the interim remedial action ROD meet the criteria for backfill or if the soil must be disposed in the ERDF.
5	Determine if contamination levels of borrow pit soil meet site criteria for use as backfill or if alternate backfill material must be used.

Table 2-4. Decision Statements. (2 pages)

DS #	Decision Statements
6	Determine if contamination levels in pipelines associated with nonradioactive sites (120-N-1, 120-N-2, and 100-N-58) meet site criteria identified in the CMS/closure plan for being left in place or if the pipelines must be removed and disposed appropriately (in the ERDF or in the inert/demolition waste landfill).
7	Determine if soils in a transition zone after the first dam in the 116-N-3 Trench exceed site cleanup criteria identified in the interim remedial action ROD and require additional remediation or if remedial action is complete.

DS = decision statement

A summary of the information contained in Tables 2-1 through 2-4 is contained in Table 2-5.

Table 2-5. Summary of DQO Step 2 Information. (4 pages)

PSQ/AA #	Principal Study Question #1 -- Do excavated contaminated soil/debris/pipelines meet ERDF waste acceptance criteria?		
	Alternative Action	Consequences	Severity of Consequences
1-1	Excavated contaminated soil/debris meets ERDF waste acceptance criteria and is disposed in the ERDF.	Excavated contaminated soil/debris is erroneously determined to meet the ERDF waste acceptance criteria and soil/debris that exceeds ERDF waste acceptance criteria is disposed in the ERDF.	Moderate
1-2	Excavated contaminated soil/debris exceeds ERDF waste acceptance criteria and cannot be disposed in the ERDF and alternative disposal options need to be evaluated.	Excavated contaminated soil/debris is erroneously determined to exceed the ERDF waste acceptance criteria and alternative disposal options are evaluated for ERDF-acceptable soil/debris.	Low
DS #1	**Decision Statement #1** -- Determine if excavated contaminated soil/debris from radioactive sites (116-N-1, 116-N-3, and UPR-100-N-31) meets ERDF waste acceptance criteria and can be disposed in the ERDF or if alternate disposal options need to be considered.		
PSQ/AA #	Principal Study Question #2 -- Does debris/piping from nonradioactive sites (120-N-1, 120-N-2, and 100-N-58) meet requirements for disposal in onsite inert/demolition waste landfills?		
	Alternative Action	Consequences	Severity of Consequences
2-1	Debris meets criteria for disposal in onsite inert/demolition waste landfills and is disposed in onsite inert/demolition landfills.	Debris from nonradioactive sites is erroneously determined to meet dangerous waste requirements and contaminated debris is disposed in an onsite inert/demolition waste landfill.	Moderate

Table 2-5. Summary of DQO Step 2 Information. (4 pages)

2-2	Debris exceeds criteria for disposal in onsite inert/demolition waste landfills and is not disposed in onsite inert/demolition landfills.	Debris from nonradioactive sites is erroneously determined to exceed dangerous waste requirements and alternative disposal options are evaluated to dispose of clean debris.	Low
DS #2	**Decision Statement #2** -- Determine if debris from nonradioactive sites (120-N-1, 120-N-2, and 100-N-58) meets requirements for disposal in onsite inert/demolition waste landfills or if alternate disposal options need to be considered.		
PSQ #3	Principal Study Question #3 [illegible] soils remaining after remediation [illegible] ROD or CMS [illegible]		
	Alternative Action	Consequences	Severity of Consequences
3-1	Soils meet criteria for protection of groundwater and direct exposure, as specified in the interim remedial action ROD or CMS/closure plan, and remediation efforts are ended.	Residual site contamination levels are erroneously determined to meet acceptable limits and remediation efforts are resulted in leaving unacceptable levels of contamination at the site.	Severe
3-2	Soils exceed criteria for protection of groundwater and direct exposure, as specified in the interim remedial action ROD or CMS/closure plan, and remediation efforts are continued.	Residual site contamination levels are erroneously determined to exceed acceptable limits and remediation efforts continue to cleanup an already clean site.	Low
DS #3	**Decision Statement #3** -- Determine if soils remaining after remediation exceed site cleanup criteria identified in the interim remedial action ROD or CMS/closure plan and require additional remediation or if remedial action is complete.		
PSQ #4	Principal Study Question #4 [illegible] overburden and layback [illegible]		
	Alternative Action	Consequences	Severity of Consequences
4-1	Overburden and layback soil meet criteria for protection of groundwater and direct exposure, as specified in the interim remedial action ROD, and are used as backfill.	Contamination levels of overburden and layback soil are erroneously determined to be within limits acceptable for use as backfill, and contaminated overburden and layback soil are used as backfill.	Severe
4-2	Overburden and layback soil exceed criteria for protection of groundwater and direct exposure, as specified in the interim remedial action ROD, and are disposed of as contaminated waste.	Contamination levels of overburden and layback soil are erroneously determined to exceed limits acceptable for use as backfill, and clean overburden and layback soil are disposed of as contaminated waste.	Low

Table 2-5. Summary of DQO Step 2 Information. (4 pages)

DS #4	**Decision Statement #4 --** Determine if contamination levels of overburden and layback soil exceed site criteria identified in the interim remedial action ROD for meet criteria for backfill or if the soil must be disposed in the ERDF.		
PSQ /AA #	**Principal Study Question #5 -- Does imported soil from onsite borrow pits meet criteria for use as backfill?**		
	Alternative Action	**Consequence**	**Severity of Consequences**
5-1	Imported soil from onsite borrow pits meets criteria for use as backfill and is used for backfill.	Imported soil from onsite borrow pits is erroneously determined to meet limits acceptable for use as backfill and the site is backfilled with contaminated soil.	Low
5-2	Imported soil from onsite borrow pits exceeds criteria for use as backfill and is not used for backfill.	Imported soil from onsite borrow pits is erroneously determined to exceed limits acceptable for use as backfill and the site is backfilled with clean soil from alternative sources.	Low
DS #5	**Decision Statement #5 --** Determine if contamination levels of borrow pit soil meet site criteria identified in the interim remedial action ROD for use as backfill or if alternate backfill material must be used.		
PSQ /AA #	**Principal Study Question #6 -- Do pipelines from nonradioactive sites (120-N-1, 120-N-2, and 100-N-58) meet criteria for being left in place?**		
	Alternative Action	**Consequence**	**Severity of Consequences**
6-1	Pipelines meet the requirements established in the CMS/closure plan for clean sites and are left in place.	Contamination levels of pipelines associated with the 120-N-1, 120-N-2, and 100-N-58 sites are erroneously determined to meet criteria for the pipelines to be left in place and contaminated pipelines are left in place.	Low
6-2	Pipelines exceed the requirements established in the CMS/closure plan for clean sites and are removed.	Contamination levels of pipelines associated with the 120-N-1, 120-N-2, and 100-N-58 sites are erroneously determined to exceed criteria for the pipelines to be left and clean pipelines are excavated and disposed of in a landfill.	Low
DS #6	**Decision Statement #6 --** Determine if contamination levels in pipelines associated with nonradioactive sites (120-N-1, 120-N-2, and 100-N-58) meet site criteria identified in the CMS/closure plan for being left in place or if the pipelines must be removed and disposed appropriately (ERDF or inert/demolition waste landfill).		

Table 2-5. Summary of DQO Step 2 Information. (4 pages)

	[illegible]		
	Alternative Action	Consequences	Severity of Consequences
7-2	A transition zone near the first dam is identified beyond which remedial action (excavation of contaminated soil) is not needed.	Contamination levels in a transition zone near the first dam are erroneously determined to meet acceptable limits and no remediation actions are taken beyond this transition zone leaving unacceptable levels of contamination at the site.	Severe
7-2	A transition zone near the first dam is identified beyond which additional remedial action (excavation of contaminated soil) is needed.	Contamination levels in a transition zone near the first dam are erroneously determined to exceed acceptable limits and remediation actions are taken beyond this transition zone to cleanup an already clean site.	Low
DS #7	**Decision Statement #7** -- Determine if soils in a transition zone after the first dam in the 116-N-3 Trench exceed site cleanup criteria identified in the interim remedial action ROD and require additional remediation or if remedial action is complete.		

3.0 STEP 3 – IDENTIFY INPUTS TO THE DECISION

3.1 PURPOSE

The purpose of DQO Step 3 is to identify the informational inputs that will be required to resolve PSQs and determine which inputs require environmental measurements, model computations, and/or sampling.

3.2 WORKSHEETS FOR STEP 3 – IDENTIFY THE INPUTS TO THE DECISION

Table 3-1 defines the informational needs, data requirements, and data acquisition methods for this DQO process.

Table 3-1. Informational Needs, Data Requirements, and Data Acquisition Methods. (2 pages)

[illegible]	[illegible] Informational Need	Type of Data Required	Computational Methods that Satisfy the Informational Need	[illegible] Methods that Satisfy Informational Need
1	Chemical and radiochemical	Alpha, beta, and gamma isotopic concentrations and toxicity characteristic determination for metals in soils, sediments, and exposed surfaces of concrete and piping.	Correlation of analytical data with field surveys of radionuclides.	Field measurements with limited analytical laboratory confirmation.
2	Chemical	Toxicity characteristic determination for metals in exposed surfaces of debris.	Direct comparison to dangerous waste limits.	Analytical laboratory confirmation.
3	Chemical and radiochemical	Chemical and radiochemical concentrations in soil and sediments.	Calculate direct exposure and impact to vadose zone, groundwater and Columbia River using the RESRAD model.	Analytical laboratory determination of radionuclide concentrations in soils followed by calculation of impact to the vadose zone, groundwater, and the Columbia River using the RESRAD model.

Table 3-1. Informational Needs, Data Requirements, and Data Acquisition Methods. (2 pages)

PSQ #	Environmental Variable Informational Need	Type of Data Required	Computational Methods that Satisfy the Informational Need	Survey/Sampling Methods that Satisfy Informational Need
4	Chemical and radiochemical	Chemical and radiochemical concentrations in overburden and layback soil.	Calculate direct exposure and impact to vadose zone, groundwater, and Columbia River using the RESRAD model.	Analytical laboratory determination of radionuclide concentrations in soils followed by calculation of impact to the vadose zone, groundwater, and the Columbia River using the RESRAD model.
5	Radiochemical	Field screening surveys.	None.	Historical knowledge and field surveys.
6	Chemical	Contamination levels in exposed surfaces of pipelines.	Direct comparison to dangerous waste limits.	Analytical laboratory confirmation.
7	Chemical and radiochemical	Chemical and radiochemical concentrations in soil.	Calculate direct exposure and impact to vadose zone, groundwater and Columbia River using the RESRAD model.	Analytical laboratory determination of radionuclide concentrations in soils followed by calculation of impact to the vadose zone, groundwater, and the Columbia River using the RESRAD model.

Table 3-2 lists the potential computation methods.

Table 3-2. List of Potential Computational Methods.

[illegible]	Computational Method	Source/Author	[illegible]	[illegible]
1	Direct comparison of analytical data with field surveys	See calculation in Appendix A	Residual radioactive material in the waste sites will cause high background radiation. This will make it difficult to provide real-time analysis of the waste unless the radioactivity from the waste can be tied to the dose rates detected in the waste.	Yes
2, 5, and 6	None	N/A	N/A	N/A
3, 4, and 7	RESRAD	*Manual for Implementing Residual Radioactive Material Guidelines*, ANL/EAD/LD-2 (ANL 1993)	Analytical laboratory determination of chemical and radionuclide concentrations in soils, surfaces of concrete and pipes, followed by calculation of impact to vadose zone soils, groundwater, and Columbia River using the RESRAD model.	Yes

N/A = not applicable

Table 3-3 identifies the type of information needed to perform a quantitative assessment for the alternative actions identified in DQO Step 2 as having severe decision error consequences.

Table 3-3. Required Information for Quantitative Assessment. (2 pages)

[illegible]	[illegible]	Risk: Human Health	Risk: Ecological
1-1	Moderate	Moderate	Moderate
1-2	High	Low	Low
2-1	Low	Moderate	Moderate
2-2	Low	Low	Low
3-1	Low	Severe	Severe
3-2	Moderate	Low	Low
4-1	Low	Severe	Severe
4-2	Moderate	Low	Low
5-1	Low	Low	Low

Table 3-3. Required Information for Quantitative Assessment. (2 pages)

PSQ # AA #	Required Information to Assess Impact		
	Cost	Risk	
		Human Health	Ecological
5-2	Moderate	Low	Low
6-1	Low	Low	Low
6-2	High	Low	Low
7-1	Moderate	Severe	Severe
7-2	Moderate	Low	Low

The sources for the information needed to resolve the PSQs are identified in Table 3-4 (e.g., previous data collection efforts, historical records, regulatory guidance, professional judgment, scientific literature, new data collections, and engineering standards). Existing appropriate data will be evaluated quantitatively in DQO Step 7.

Table 3-4. Required Information and Reference Sources. (2 pages)

PSQ #	Required Information	Do Data Exist? (Y/N)	Source Reference	Sufficient Quality (Y/N)	Add'l Data Req'd (Y/N)
1	Alpha, beta, and gamma isotopic concentrations and toxicity characteristic determination for metals in soils, sediments, and exposed surfaces of concrete and piping	Y	Data summary report (BHI 1999c)	N	Y
2	Chemical data from debris	N		N	Y
3	Chemical and radiochemical concentrations in soil and sediments remaining after excavation	N		N	Y
4	Chemical and radiochemical concentrations in overburden and layback soil	N		N	Y

Table 3-4. Required Information and Reference Sources. (2 pages)

[illegible]	Required Information	[illegible]	Source Reference	[illegible]	[illegible]
5	Chemical and radiochemical concentrations in soil	Y	Process history/knowledge	N	Y
6	Chemical concentrations in exposed surfaces of pipelines	N		N	Y
7	Chemical and radiochemical concentrations in soil	N		N	Y

The following information is contained in Table 3-5:

- Identification of the information needed to establish the action levels.
- Definition of the preliminary action levels (see DQO Step 1, Table 1-11, which summarizes the site-specific ARARs).
- Definition of the basis for setting the action levels. The action level is the threshold value that provides the criterion for choosing between alternative actions. Action levels may be based on regulatory thresholds or standards, or the levels may be derived from problem-specific considerations such as risk analysis. The actual numerical action level will be set in DQO Step 5.

Table 3-5. Basis for Setting Preliminary Action Levels. (4 pages)

DS #	Media	COCs	Preliminary Action Level	Basis
		Radionuclides (pCi/g)		
1	Soil, concrete structures, and pipelines	Americium-241	25,500	*Environmental Restoration Disposal Facility Waste Acceptance Criteria* (BHI 1998a) radionuclide limits are based on a soil density of 1.96 metric ton/m^3.
		Cesium-137	16,300,000	
		Cobalt-60	No limit	
		Europium-154	No limit	
		Europium-155	No limit	
		Nickel-63	3.57E+08	
		Plutonium-238	765,000	
		Plutonium-239/240	14,000	
		Strontium-90	3.6E+09	
		Tritium	No limit	
		Uranium-233/234	37,700	
		Uranium-235	1,300	
		Uranium-238+dau	6,100	

Table 3-5. Basis for Setting Preliminary Action Levels. (4 pages)

DS	Media	COPC	Preliminary Action Level	Basis
		Metals (mg/kg)		
		Antimony	19,000	
		Arsenic	3,000	
		Barium	940,000	
		Cadmium	39,000	
		Chromium (total)	59,000	
		Chromium (VI)	59,000	
		Lead	No limit	
		Manganese	440,000	
		Nickel	No limit	
		Selenium	400,000	
		Silver	350,000	
		Vanadium	330,000	
		Zinc	300,000	
		Mercury	No limit	
		Nitrate	No limit	
		pH (pH units)	<2 or >12.5	
		Sulfate	No limit	
		TCLP (mg/L)		
		Arsenic	5	
		Barium	100	
		Cadmium	1	
		Chromium (total)	5	
		Lead	5	
		Selenium	5.7	
		Silver	5	
		Mercury	0.2	
2	Soil, liner, and concrete from 120-N-1, 120-N-2, 100-N-58, and associated pipelines	**TCLP (mg/L)**		WAC 173-303-090
		Arsenic	5	
		Barium	100	
		Cadmium	1	
		Chromium (total)	5	
		Lead	5	
		Mercury	0.2	
		Selenium	1	
		Silver	5	
		pH (pH units)	<2 or >12.5	

Table 3-5. Basis for Setting Preliminary Action Levels. (4 pages)

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3,4, 5, and 7	Surface (0 to 4.6 m [0 to 15 ft] bgs) soil, concrete structures, and pipelines radiological sites	**Radionuclides (pCi/g)**		Values for radionuclides from the interim remedial action ROD (Ecology et al. 2000). Values for americium-241 and nickel-63 are not included in the interim remedial action ROD but were calculated using RESRAD (ANL 1993) and represent the 15 mrem/yr limit (surface soil).
		Americium-241	41.6	
		Cesium-137	6.1	
		Cobalt-60	1.4	
		Europium-154	3.1	
		Europium-155	127	
		Nickel-63	4,031	
		Plutonium-239/240	23.5	
		Strontium-90	3.7	
		Tritium	241	
		Inorganics (mg/kg)		MTCA Method B
		Chromium (VI)	400	
		Mercury	24	
		Nitrate	113,000	
	Subsurface (>4.6 m [>15 ft] bgs) soil, concrete structures, and pipelines radiological sites	**Radionuclides (pCi/g)**		Values for radionuclides from the interim remedial action ROD (Ecology et al. 2000). Americium-241, nickel-63, and strontium-90 are not calculated to reach groundwater within a 1,000-year time frame.
		Americium-241	N/A	
		Nickel-63	N/A	
		Plutonium-239/240	N/A	
		Strontium-90	N/A	
		Tritium	2,000	
		Inorganics (mg/kg)		Values for inorganics from the interim remedial action ROD (Ecology et al. 2000). Mercury is not calculated to reach groundwater within a 1,000-year time frame.
		Chromium (VI)	2	
		Mercury	N/A	
		Nitrate	4,400	

Table 3-5. Basis for Setting Preliminary Action Levels. (4 pages)

DS #	Media	COPC	Preliminary Action Level	Basis
		Inorganics (mg/kg)		
3 and 6	120-N-1, 120-N-2, 100-N-58 soil, and associated pipelines	Antimony	32	Data are MTCA Method B values, unless otherwise indicated.
		Arsenic	20[a]	
		Barium	5,600	
		Beryllium	400	
		Chromium (VI)	400	
		Copper	2,960	
		Lead	353[b]	
		Manganese	11,200	
		Mercury	24	
		Nickel	1,600	
		Selenium	400	
		Sulfate	25,000[c]	
		Thallium	6	
		Vanadium	560	
		Zinc	24,000	

[a] Arsenic limits are from MTCA Method A due to high background values per discussions with regulators.
[b] MTCA Method B value for lead is not available. This value is based on EPA's *Integrated Exposure Uptake Biokinetic Model for Lead in Children* (EPA 1994a).
[c] Based on 100 times the PRG for groundwater/Columbia River protection.
N/A = not applicable
TCLP = toxicity characteristic leachate procedure

Table 3-6 lists the information needed to perform the DQO Step 6 quantitative assessment of the alternative actions identified in DQO Step 2 with severe decision error consequences. This information should evaluate the impact to cost, risk to human health and the environment, and schedule.

Table 3-6. Quantitative Assessment of Decision Error Consequences. (2 pages)

DS/AA #	Consequences of Decision Error			
	Incremental Cost Above Project Baseline	Human Health Risk	Environmental Risk	Schedule
1-1	Moderate	Moderate	Moderate	July 2000 through June 2003
1-2	High	Low	Low	July 2000 through June 2003
2-1	Low	Moderate	Moderate	July 2000 through June 2003
2-2	Low	Low	Low	July 2000 through June 2003
3-1	Low	Severe	Severe	July 2000 through June 2003
3-2	Moderate	Low	Low	July 2000 through June 2003

Table 3-6. Quantitative Assessment of Decision Error Consequences. (2 pages)

[illegible]	Consequences of Decision Error			
	[illegible] Project Baseline	Human Health Risk	Environmental Risk	Schedule
4-1	Low	Severe	Severe	July 2000 through June 2003
4-2	Moderate	Low	Low	July 2000 through June 2003
5-1	Low	Low	Low	July 2000 through June 2003
5-2	Moderate	Low	Low	July 2000 through June 2003
6-1	Low	Low	Low	July 2000 through June 2003
6-2	High	Low	Low	July 2000 through June 2003
7-1	Moderate	Severe	Severe	July 2000 through June 2003
7-2	Moderate	Low	Low	July 2000 through June 2003

It is essential to confirm that appropriate measurement methods exist to provide the necessary data. It should be noted that the consequences of decision error (in DQO Step 6) will determine the level of analysis required (e.g., field screening or fixed laboratory). Table 3-7 develops a list of potentially appropriate measurement methods.

Table 3-7. Appropriate Measurement Methods.

WS #	Media	Environmental Variable	Potentially Appropriate Measurement Method	Possible Limitations of [illegible]
1 and 5	All	Screening concentration	Field instruments (e.g., NaI, XRF, and soil gas analyzer); radiation counting facilities; quick turnaround laboratories (HPGe)	Background radiation levels are relatively high in these areas. Detection limits not as low as remediation goals (to 15 mrem/yr or MTCA Method B) and may not detect low levels that could also require remediation.
All	All	Verification sampling concentration	Standard fixed laboratory methods (e.g., AEA, GeLi, HPGe, and EPA Methods 6010 or 7471)	Cost and turnaround time.

[a] Other methods may be identified and implemented in conjunction with technology development.
AEA = alpha energy analysis
GeLi = germanium-lithium
HPGe = high-purity germanium
NaI = sodium iodide
XRF = x-ray fluorescence

The method detection limit, action level, limit of quantitation, precision, and accuracy requirements for each potential method are identified in Table 3-8.

Table 3-8. Analytical Performance Requirements. (4 pages)

Data Type	Analytical Method	Analyte	Data Use	Preliminary Action Level	Detection Limit Requirements		Accuracy Req't (% Recovery)	Precision Req't (% RPD or RSD)
					MDL	PQL		
[illegible]								
Radio-isotopes[a]	Chemical separation - alpha energy analysis	Americium-241	Disposal Cleanup, shallow Cleanup, deep	25,500 41.6 N/A	0.1	1	70-130	±30
	Gamma energy analysis	Cesium-137	Disposal Cleanup, shallow Cleanup, deep	16,300,000 6.1 N/A	0.05	0.1	80-120	±30
		Cobalt-60	Disposal Cleanup, shallow Cleanup, deep	No limit 1.4 N/A	0.02	0.05	80-120	±30
		Europium-154	Disposal Cleanup, shallow Cleanup, deep	No limit 3.1 N/A	0.1	0.1	80-120	±30
		Europium-155	Disposal Cleanup, shallow Cleanup, deep	No limit 127 N/A	0.2	0.1	80-120	±30
	Chemical separation - alpha energy analysis	Plutonium-239/240	Disposal Cleanup, shallow Cleanup, deep	14,000 23.5 N/A	0.1	1	70-130	±30
	Chemical separation - gas proportional	Nickel-63	Disposal Cleanup, shallow Cleanup, deep	3.57E+08 4,031 50	5	30	70-130	±30
		Strontium-90	Disposal Cleanup, shallow Cleanup, deep	3.6E+9 3.7 706	0.2	1	70-130	±30
	Chemical separation - liquid scintillation	Tritium	Disposal Cleanup, shallow Cleanup, deep	No limit 241 2,000	5	400	70-130	±30

Table 3-8. Analytical Performance Requirements. (4 pages)

Data Type	Analytical Method	Analyte	Data Use	Preliminary Action Level	Detection Limit Requirements		Accuracy Req't (% Recovery)[a]	Precision Req't (RPD or RSD)
					MDL	PQL		
Chemical[b]	Total metals by SW-846 Method 6010 – ICP Lower detection limit [in brackets] by trace technology TCLP analysis (in parenthesis) by SW-846 Method 1311, extraction – Method 6010 - ICP	Antimony	Disposal Cleanup, shallow Cleanup, deep	No limit 32 N/A	2	6	70-130	±30
		Arsenic	Disposal Cleanup, shallow Cleanup, deep	3,000 (5) 20[c] N/A	3 (0.02)	10 (0.1)	70-130	±30
		Barium	Disposal Cleanup, shallow Cleanup, deep	940,000 (100) 5,600 N/A	2 (0.05)	20 (0.20)	70-130	±30
		Beryllium	Disposal Cleanup, shallow Cleanup, deep	No limit 400 N/A	0.2	0.5	70-130	±30
		Cadmium	Disposal Cleanup, shallow Cleanup, deep	39,000 (1) 80 N/A	0.2 (0.003)	0.5 (0.005)	70-130	±30
		Chromium (total)	Disposal Cleanup, shallow Cleanup, deep	59,000 (5) 80,000 N/A	0.4 (0.005)	1 (0.01)	70-130	±30
		Copper	Disposal Cleanup, shallow Cleanup, deep	No limit 2,960 N/A	0.5	2.5	70-130	±30
		Lead	Disposal Cleanup, shallow Cleanup, deep	No limit (5) 353 N/A	3 (0.04)	10 (0.1)	70-130	±30
		Manganese	Disposal Cleanup, shallow Cleanup, deep	No limit 11,200 N/A	0.4	1.5	70-130	±30
		Nickel	Disposal Cleanup, shallow Cleanup, deep	No limit 1,600 N/A	1	4	70-130	±30
		Selenium	Disposal Cleanup, shallow Cleanup, deep	400,000(1) 400 N/A	5 (0.05)	10 (0.1)	70-130	±30

Table 3-8. Analytical Performance Requirements. (4 pages)

Data Type	Analytical Method	Analyte	Data Use	Preliminary Action Level	Detection Limit Requirements		Accuracy Req't (% Recovery)	Precision Req't (% RSD or RSD)
					MDC	PQL		
		Silver	Disposal Cleanup, shallow Cleanup, deep	350,000(5) 400 N/A	0.5 (0.005)	2 (0.02)	70-130	±30
		Thallium	Disposal Cleanup, shallow *Cleanup, deep*	No limit 5.6 N/A	4	10 [1]	70-130	±30
		Vanadium	Disposal Cleanup, shallow Cleanup, deep	No limit 560 N/A	2	5	70-130	±30
		Zinc	Disposal Cleanup, shallow Cleanup, deep	No limit 24,000 N/A	0.5	2	70-130	±30
	Total Hg by SW-846 Method 7471 – CVAA. TCLP analysis (in parenthesis) by SW-846 Method *1311, extraction* – Method 7470 - CVAA	Mercury	Disposal Cleanup, shallow Cleanup, deep	No limit (0.2) 24 24	0.02 (0.001)	0.2 (0.001)	70-130	±30
	SW-846 Method 7196	Chromium (VI)	Disposal Cleanup, shallow Cleanup, deep	59,000 400 400	0.4	0.5	70-130	±30
	EPA Method 353/300	*Nitrate plus nitrite* as nitrogen	Disposal Cleanup, shallow Cleanup, deep	No limit 113,000 4,400	0.2	0.75	70-130	±30

Table 3-8. Analytical Performance Requirements. (4 pages)

Data Type	Analytical Method	Analyte	Data Use	Preliminary Action Level	Detection Limit Requirements		Accuracy Req't (% Recovery)	Precision Req't (%RSD or RPD)
					MDL	PQL		
	SW-846 Method 9045	pH (pH units)	Disposal Cleanup, shallow Cleanup, deep	<2 or >12.5 <2 or >12.5 N/A	0.5	0.1	NA	NA
	SW-846 Method 9056	Sulfate	Disposal Cleanup, shallow Cleanup, deep	No limit N/A N/A	2	5	70-130	±30
Performance Requirements for Field Measurements								
Radio-isotopes[a]	Portable NaI detector	Gross Cs-137 counts	Disposal Cleanup, shallow Cleanup, deep	44,900[d] 6.1 N/A	100[e]	N/A	±80-120	±20

[a] Radioisotopes measured in pCi/g.
[b] Inorganics/metals measured in mg/kg; TCLP measured in mg/L.
[c] Arsenic limits are from MTCA Method A due to high background values per discussions with regulators.
[d] Per ERDF hazard classification basis concentrations.
[e] This is based on (1) 2x2 NaI detector with a 300-kev window (lower energy cut-off), (2) a 500 count per minute background, (3) a 5-minute background count, (4) a 1-minute sample count, (5) 1% efficiency for cesium-137, and (6) a sample size of 800 g soil (or a 500-mL Marinelli beaker with a sample density of 1.6 g/cm^3).

CVAA = cold vapor atomic absorption
ICP = inductively coupled plasma
MDL = minimum detectable level
N/A = not applicable

4.0 STEP 4 -- DEFINE THE BOUNDARIES OF THE STUDY

4.1 PURPOSE

The primary objective of DQO Step 4 is for the DQO Team to identify the spatial, temporal, and practical constraints on the sampling design and consider the consequences. This objective (in terms of the spatial, temporal, and practical constraints) is to ensure that the sampling design results in the collection of data that accurately reflect the true condition of the site and/or populations being studied.

4.2 WORKSHEETS FOR STEP 4 -- DEFINE THE BOUNDARIES OF THE STUDY

Table 4-1 defines the spatial and temporal boundaries of the study to clarify what the samples are intended to represent. The characteristics that define the population of interest are also identified.

Table 4-1. Characteristics that Define the Population of Interest.

DS #	WS #	Population of Interest	Characteristic	Unit Measurement Size	Total Number of Sampling Measurement Units Within the Population
1 - 7	1	116-N-1 Crib and associated pipelines, and UPR-100-N-31	Radioactivity levels, TCLP results	1 L	1.4E+10
1 - 7	2	116-N-1 Trench and cover panels	Radioactivity levels, TCLP results	1 L	1.3E+10
1 - 7	3	116-N-3 Crib, Trench, cover panels, and associated pipelines	Radioactivity levels, TCLP results	1 L	1.7E+10
1 - 7	4	120-N-1, 120-N-2, 100-N-58, and associated pipelines	Metals, sulfate, pH, and nitrate results	1 L	1.0E+10

Table 4-2 defines the spatial boundaries of the decision and the domain or geographic area (or volume) within which all decisions must apply (in some cases, this may be defined by the operable unit). The domain is a region distinctly marked by physical features (i.e., volume, length, width, and boundary). Refer to Figure 1-1 for a map of the area.

Table 4-2. Geographic Areas of Investigation.

DS #	Geographic Areas of Investigation
1	Excavated contaminated soil from the 116-N-1 Crib and Trench, UPR-100-N-31, 116-N-3 Crib and Trench, and associated pipelines.
2	Debris (liner and other debris that contacted liquid effluents) from the 120-N-1, 120-N-2, and 100-N-58 percolation pond system.
3	Surfaces of the 116-N-1 Crib and Trench, UPR-100-N-31, 116-N-3 Crib and Trench, and northern part of 120-N-1, 120-N-2, and 100-N-58 percolation pond system as specified in the CMS/closure plan.
4	Overburden/layback piles from the 116-N-1 Crib and Trench, UPR-100-N-31, and 116-N-3 Crib and Trench.
5	Exposed surface of borrow pit sites used as a source for backfill.
6	Pipelines associated with the 120-N-1, 120-N-2, and 100-N-58 percolation pond system.
7	The floor of the 116-N-3 Trench in roughly 10 m (30 ft) in length downstream of the first dam.

When appropriate, the population is divided into strata that have relatively homogeneous characteristics. The DQO team must systematically evaluate process knowledge, historical data, and plant configurations to present evidence of a logic that supports alignment of the population into strata with homogeneous characteristics. Table 4-3 identifies the strata with homogeneous characteristics. Figures 4-1 and 4-2 provide graphical representations of these strata.

Table 4-3. Strata with Homogeneous Characteristics. (2 pages)

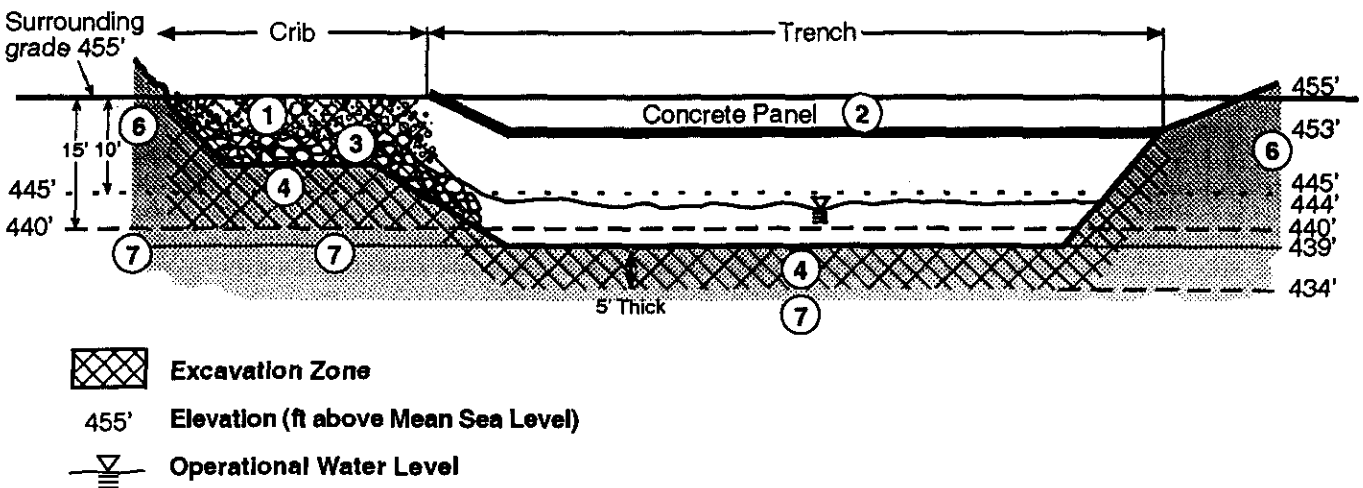
DS	Decision Statement	WS	Geographical Area of Interest	Strata	Homogeneous Characteristic Logic
1	Determine if excavated contaminated soil/debris from radioactive sites (116-N-1, 116-N-3 and UPR-100-N-31) meets ERDF waste acceptance criteria and can be disposed in the ERDF or if alternate disposal options need to be considered.	1	116-N-1 Crib and associated pipelines	• Layer of contaminated boulders and cobbles • Contaminated native soil • Contaminated pipelines/debris	Each stratum was exposed to the same process.
		1	UPR-100-N-31	• Contaminated native soil	
		2	116-N-1 Trench and cover panels	• Cover panels • Contaminated native soil	
		3	116-N-3 Crib and Trench, cover panels, and associated pipelines	• Cover panels • Contaminated native soil • Contaminated pipelines/debris	
		4	120-N-1, 120-N-2, 100-N-58, and associated pipelines	• Liner • Pipelines • Debris • Soil remaining after excavation	
3	Determine if soils remaining after remediation exceed site cleanup criteria identified in the interim remedial action ROD and require additional remediation or if remedial action is complete.	1	116-N-1 Crib and associated pipelines	• Surface soil remaining after excavation • Subsurface soil remaining after excavation	Each stratum was exposed to the same process.
		1	UPR-100-N-31	• Surface soil remaining after excavation • Subsurface soil remaining after excavation	
		2	116-N-1 Trench and cover panels	• Surface soil remaining after excavation • Subsurface soil remaining after excavation	
		3	116-N-3 Crib and Trench, cover panels, and associated pipelines	• Surface soil remaining after excavation • Subsurface soil remaining after excavation	
		4	120-N-1, 120-N-2, 100-N-58, and associated pipelines	• Soil remaining at nonradioactive contaminated sites	
4	Determine if contamination levels of overburden and layback soil exceed site criteria identified in the interim remedial action ROD for meet criteria for backfill or if the soil must be disposed in the ERDF.	1	116-N-1 Crib and associated pipelines	• Overburden/layback soils	Each stratum was exposed to the same process.
		1	UPR-100-N-31	• Overburden/layback soils	
		2	116-N-1 Trench and cover panels	• Overburden/layback soils • Cover panels	
		3	116-N-3 Crib and Trench, cover panels, and associated pipelines	• Overburden/layback soils • Cover panels	
		4	120-N-1, 120-N-2, 100-N-58, and associated pipelines	• None	

Table 4-3. Strata with Homogeneous Characteristics. (2 pages)

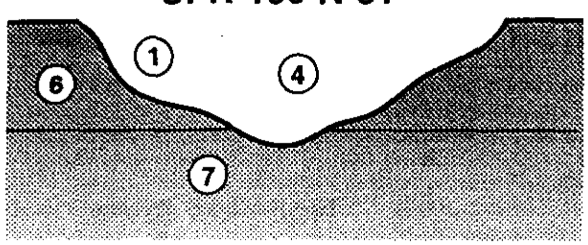
DS #	Decision Statement	WS #	Geographical Area of Interest	Strata	Homogeneous Characteristic Logic
5	Determine if contamination levels of borrow pit soil meet site criteria identified in the interim remedial action ROD for use as backfill or if alternate backfill material must be used.	1, 2, 3, and 4	116-N-1 Crib, Trench, cover panels, and associated pipelines; UPR-100-N-31; 116-N-3 Crib and Trench, cover panels, and associated pipelines; and 120-N-1, 120-N-2, 100-N-58, and associated pipelines	• Borrow pit soil	Borrow pits are in areas that were never exposed to radioactive contaminants.
6	Determine if contamination levels in pipelines associated with nonradioactive sites (120-N-1, 120-N-2, and 100-N-58) meet site criteria identified in the CMS/closure plan for being left in place or the pipelines must be removed and disposed appropriately (ERDF or inert/demolition waste landfill).	4	120-N-1, 120-N-2, and 100-N-58 associated pipelines	• Pipelines	Pipelines were exposed to the same process.
7	Determine if soils in a transition zone after the first dam in the 116-N-3 Trench exceed site cleanup criteria identified in the interim remedial action ROD and require additional remediation or if remedial action is complete.	3	116-N-3 Crib and Trench, cover panels, and associated pipelines	• Subsurface soil	Each stratum was exposed to the same process.

Figure 4-1. Strata Associated with the 116-N-1 and UPR-100-N-31 Sites.

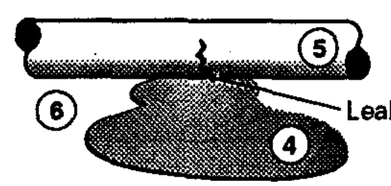
116-N-1 Cross Section



UPR-100-N-31



Feed Pipe

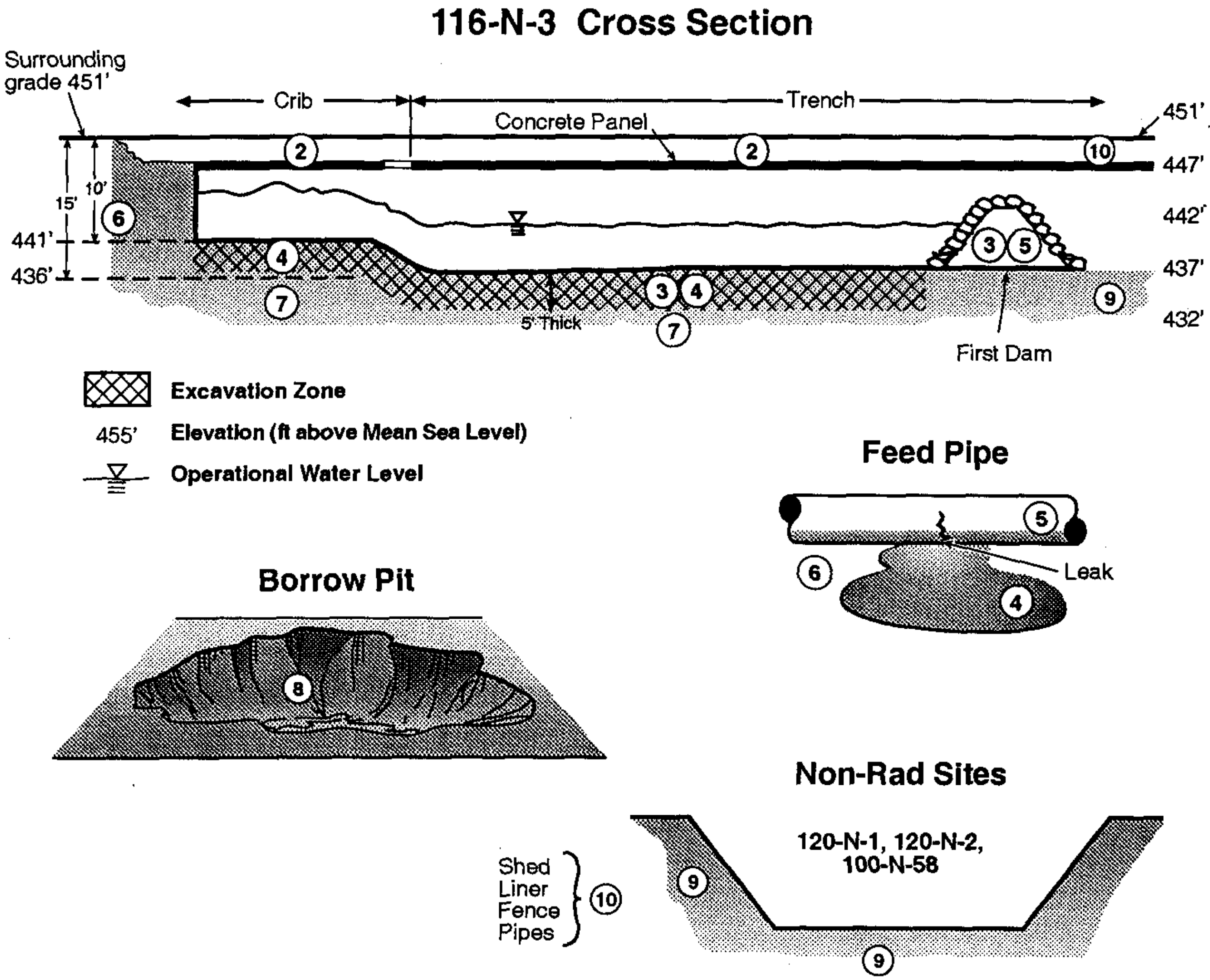


Key

1. Overburden/layback soils
2. Potentially contaminated cover panels
3. Excavated boulders and cobbles
4. Excavated native soil
5. Excavated pipe/debris
6. Surface soil remaining after excavation, rad sites
7. Suburface soil remaining after excavation, rad sites
8. Borrow pit soil
9. Soil remaining at non-rad contaminated sites
10. Debris removed from non-rad contaminated sites

E9912070.1

Figure 4-2. Strata Associated with the 116-N-3 and Nonradioactive Sites and Borrow Pits.



Key

1. Overburden/layback soils
2. Potentially contaminated cover panels
3. Excavated boulders and cobbles
4. Excavated native soil
5. Excavated pipe/debris
6. Surface soil remaining after excavation, rad sites
7. Suburface soil remaining after excavation, rad sites
8. Borrow pit Soil
9. Soil remaining at non-rad contaminated sites
10. Debris removed from non-rad contaminated sites

E9912070.2

Table 4-4 defines the spatial scale of decision making (defines each decision unit that is the smallest area or volumetric unit for which each decision applies). Decision units may be remediation units or risk units.

Table 4-4. Spatial Scale of Decision Making.

DS #	Spatial Scale of Decision Making
1	Each ERDF roll-on/roll-off container load of contaminated waste.
2	Volume of each waste stratum sent to inert/demolition landfill.
3	Shallow zone: Excavation exposed surface area 0 to 4.6 m (0 to 15 ft) bgs. Deep zone: Excavation exposed surface area deeper than 4.6 m (15 ft) bgs.
4	Volume of excavated overburden/layback from each waste site.
5	Exposed surface area of soil at each borrow pit to be used as backfill.
6	Interior surfaces of pipelines.
7	A transition zone of the floor of the 116-N-3 Trench approximately 10-m (30-ft) long.

The temporal boundaries of the decision are defined in Tables 4-5 and 4-5a.

Table 4-5. Sampling Time Frame and Sampling Design Rigor Requirements.

DS #	Time Frame	Qualified Consequences of Inadequate Sampling Design	Resulting Access and Remedial/Disposal Actions	Required Sampling Design Rigor
1	During remediation (July 2000 to June 2003)	Not severe	Not accessible	Moderate
2	During remediation (July 2000 to June 2003)	Not severe	Not accessible	Moderate
3	At completion of remediation (approximately July 2003)	Severe	Accessible	Robust
4	During remediation (July 2000 to June 2003)	Severe	Accessible	Robust
5	Before backfill (approximately July 2003)	Not severe	Accessible	Low
6	During remediation (July 2000 to June 2003)	Not Severe	Accessible	Moderate
7	During remediation (July 2000 to June 2003)	Severe	Accessible	Robust

Table 4-5a. Consequences, Resampling Access, and Sampling Design Rigor Requirements.

Consequences of Action	Resampling Access After Remedial Actions	Sampling Design Rigor Requirement
Severe	Inaccessible	Very robust
Severe	Accessible	Robust
Not severe	Inaccessible	Moderate
Not severe	Accessible	Low

Table 4-6 identifies measurement objectives, conditions, and constraints in relation to when data will be collected.

Table 4-6. When to Collect Data.

Measurement	Measurement Objective	Condition	Measurement/ Condition Constraints (Time Units)
Chemical and radiochemical data	Assess levels of contaminants in soil, concrete, and pipelines	Dry weather	None

A temporal scale of decision making may be necessary for certain types of studies. For example, to regulate water quality it would be useful to set a scale of decision making that limits the time between sampling events, which would minimize the potential adverse effects in case the water quality was degraded between sampling events. The temporal scale of decision making is defined in Table 4-7.

Table 4-7. Temporal Scale of Decision Making.

DS#	Temporal Scale of Decision Making
1	During remediation.
2	During remediation.
3	After remediation but before backfill.
4	After remediation but before backfill.
5	Before backfill.
6	During remediation.
7	After remediation but before backfill.

The practical constraints on data collection are listed in Table 4-8.

Table 4-8. Practical Constraints on Data Collection.

• Sites may require sampling in areas of high radiological exposure, and the stay-time of samplers may be limited.
• High background levels of radiation may saturate field instruments.
• Difficult sample matrices (e.g., concrete, metals, and boulders) are present and may require special sample collection methods.
• Side slopes may make access by personnel and equipment difficult.

5.0 STEP 5 -- DEVELOP A DECISION RULE

5.1 PURPOSE

The purpose of DQO Step 5 is to define the parameter of interest (e.g., mean), specify the action level, and integrate outputs from the previous DQO steps into a single statement that describes a logical basis for choosing among alternative actions.

5.2 WORKSHEETS FOR STEP 5 -- DEVELOP A DECISION RULE

The statistical parameter of interest that characterizes the population is defined in Table 5-1.

Table 5-1. Statistical Parameter of Interest that Characterizes the Population. (2 pages)

DS	Decision Statement Summary	Parameter of Interest
1	Determine if excavated contaminated soil/debris from radioactive sites (116-N-1, 116-N-3, and UPR-100-N-31) meets ERDF waste acceptance criteria and can be disposed in the ERDF or if alternate disposal options need to be considered.	Direct reading of field survey instruments.
2	Determine if debris from nonradioactive sites (120-N-1, 120-N-2, and 100-N-58) meets requirements for disposal in onsite inert/demolition waste landfills or if alternate disposal options need to be considered.	Mean calculated from analytical laboratory results.
3	Determine if soils remaining after remediation exceed site cleanup criteria identified in the interim remedial action ROD and require additional remediation or if remedial action is complete.	<u>Shallow zone, metals</u>: For each metal (Ecology 1995): • The concentration that represents the population maximum • The proportion of the population concentration that exceeds the cleanup level • The true population mean.
		<u>Shallow zone, radionuclides</u>: The dose modeled from radionuclide concentrations representing the 95% UCL on the true population mean.
		<u>Deep zone, metals and radionuclides</u>: The concentration in groundwater modeled from the concentrations representing the true population mean in soil of each COC.

Table 5-1. Statistical Parameter of Interest that Characterizes the Population. (2 pages)

DS #	Decision Statement Summary	Parameter of Interest
4	Determine if contamination levels of overburden and layback soil exceed site criteria identified in the interim remedial action ROD for meet criteria for backfill or if soil must be disposed in the ERDF.	Metals (Ecology 1995): • The concentration that represents the population maximum • The proportion of the population concentration that exceeds the cleanup level • The concentration representing the true population mean. Radionuclides: The dose modeled from radionuclide concentrations representing the 95% UCL on the true population mean.
5	Determine if contamination levels of borrow pit soil meet site criteria for use as backfill or if alternate backfill material must be used.	Maximum.
6	Determine if contamination levels in pipelines associated with nonradioactive sites (120-N-1, 120-N-2, and 100-N-58) meet site criteria identified in the CMS/closure plan for being left in place or if the pipelines must be removed and disposed appropriately (ERDF or inert/demolition waste landfill).	Ecology (1995): • The concentration that represents the population maximum • The proportion of the population concentration that exceeds the cleanup level • The concentration representing the true population mean.

UCL = upper confidence limit

Table 5-2 specifies the scale of decision making.

Table 5-2. Scale of Decision Making.

DS #	Scale of Decision Making
1	Volume of excavated soil/debris in one ERDF roll-on/roll-off container.
2	Volume of each waste stratum sent to inert/demolition landfill.
3	Exposed surface of deep zone and/or shallow zone after excavation is complete.
4	Volume of overburden/layback soil stockpiled from each remediation site.
5	Exposed surface of borrow pit soil before the soil is excavated and hauled to the remediation site.
6	Length of feed pipeline.
7	The surface area of the bottom of the 116-N-3 Trench in a transition zone approximately 10-m (30-ft) long.

The action levels or preliminary action levels for each of the decision statements are specified in Table 5-3.

Table 5-3. Action Level for the Decision. (2 pages)

DS	[illegible]	Action Level	
	Radionuclides (pCi/g)		
1	Americium-241	25,500	
	Cesium-137	16,300,000	
	Cobalt-60	No limit	
	Europium-154	No limit	
	Europium-155	No limit	
	Nickel-63	3.57E+08	
	Plutonium-239/240	14,000	
	Strontium-90	3.6E+09	
	Tritium	No limit	
	Metals (mg/kg)		
	Chromium (VI)	59,000	
	Mercury	No limit	
	Nitrate	No limit	
	TCLP (mg/L)		
1 and 2	Arsenic	5	
	Barium	100	
	Cadmium	1	
	Chromium (total)	5	
	Lead	5	
	Mercury	0.2	
	Selenium	1	
	Silver	5	
	Inorganics		
	pH (pH units)	<2 or >12.5	
	Radionuclides		
3, 4, and 7	A maximum dose of 15 mrem/yr above background (direct exposure) and 4 mrem/yr[a] (groundwater protection), calculated via RESRAD.		
	Nonradionuclides (mg/kg)		
		[illegible]	Groundwater/River Protection
	Chromium (VI)	400	2
	Mercury	24	[b]
	Nitrate	113,000	4,400

Table 5-3. Action Level for the Decision. (2 pages)

DS #	Sites	Action Level
	Radionuclides	
5	Surveyed per radiation control procedures.	
	Inorganics (mg/kg)	
3 (non-radioactive sites) and 6	Antimony	32
	Arsenic	20
	Barium	5,600
	Beryllium	400
	Chromium (III)	80,000
	Chromium (VI)	400
	Copper	2,960
	Lead	353
	Manganese	11,200
	Mercury	24
	Nickel	1,600
	Selenium	400
	Sulfate	25,000[c]
	Thallium	5.6
	Vanadium	560
	Zinc	24,000

[a] The 4 mrem/yr dose is based on target organ protection from the consumption of groundwater as calculated by the NBS Handbook 69 methodology (NBS 1963).
[b] The RESRAD unit gradient model predicts the contaminant will not reach groundwater within 1,000-year time frame.
[c] Based on 100 times the PRG for groundwater/Columbia River protection.

The alternative actions are specified in Table 5-4.

Table 5-4. Alternative Actions. (2 pages)

DS #	AA #	Alternative Actions
1	1	Excavated contaminated soil/debris meets ERDF waste acceptance criteria and is disposed in the ERDF.
1	2	Excavated contaminated soil/debris exceeds ERDF waste acceptance criteria and cannot be disposed in the ERDF, and alternative disposal options need to be evaluated.
2	1	Debris meets criteria for disposal in onsite inert/demolition waste landfills and is disposed in onsite inert/demolition landfills.
2	2	Debris exceeds criteria for disposal in onsite inert/demolition waste landfills and is not disposed in onsite inert/demolition landfills.
3	1	Soils meet criteria for protection of groundwater and direct exposure, as specified in the interim remedial action ROD, and remediation efforts are ended.

Table 5-4. Alternative Actions. (2 pages)

DS #	AA #	Alternative Action
3	2	Soils exceed criteria for protection of groundwater and direct exposure, as specified in the interim remedial action ROD, and remediation efforts are continued.
4	1	Overburden and layback soil meet criteria for protection of groundwater and direct exposure as specified in the interim remedial action ROD and are used as backfill. .
4	2	Overburden and layback soil exceed criteria for protection of groundwater and direct exposure as specified in the interim remedial action ROD and are disposed of as contaminated waste.
5	1	Imported soil from onsite borrow pits meets criteria for use as backfill and is used for backfill.
5	2	Imported soil from onsite borrow pits exceeds criteria for use as backfill and is not used for backfill.
6	1	Pipelines meet the requirements established in the CMS/closure plan for clean sites and are left in place.
6	2	Pipelines exceed the requirements established in the CMS/closure plan for clean sites and are removed.
7	1	Soils meet criteria for protection of groundwater and direct exposure as specified in the interim remedial action ROD, and remediation efforts are ended beyond the first dam.
7	2	Soils exceed criteria for protection of groundwater and direct exposure as specified in the interim remedial action ROD, remediation efforts are continued in this transition zone, and a new 10-m (30-ft) transition zone is selected for evaluation.

The outputs of DQO Step 5 and the previous DQO steps are combined into "IF...THEN..." decision rules that incorporate the parameter of interest, the scale of decision making, the action level, and the actions that would result from resolution of the decision. The decision rules are listed in Table 5-5.

Table 5-5. Decision Rules. (2 pages)

DR #	Decision Rule
1	If the contaminant concentration of any COC calculated from field surveys exceeds the ERDF waste acceptance criterion for that radionuclide, then the waste cannot be disposed of in the ERDF and alternative disposal options will be investigated.
2	If the true mean contaminant leachate concentration of any COC calculated from laboratory analysis exceeds LDR limits, then the waste cannot be disposed of in an onsite inert/demolition landfill and alternative disposal options will be investigated.

Table 5-5. Decision Rules. (2 pages)

DR #	Decision Rule
3	For soil samples collected from the shallow zone of a remediation site: If the concentration representing the 95% UCL on the true population mean for each inorganic COC does not exceed the MTCA Method B cleanup level for that inorganic, no inorganic COC concentration exceeds twice the MTCA Method B cleanup level, no more than 10% of the inorganic COC concentrations exceed the MTCA Method B cleanup level, total hazard index is less than one, total excess cancer risk is less than one in 100,000, and the dose rate calculated from the 95% UCL on the true population mean for each radionuclide and the total COCs does not exceed 15 mrem/yr above background levels, then the shallow zone of the site will be designated as remedied and site closeout can proceed.
4	For samples of overburden/layback and concrete debris: If the concentration representing the 95% UCL on the true population mean for each inorganic COC does not exceed the MTCA cleanup level for that inorganic, no inorganic COC concentration exceeds twice the MTCA cleanup level, no more than 10% of the inorganic COC concentrations exceed the MTCA cleanup level, total hazard index is less than one, total excess cancer risk is less than one in 100,000, and the dose rate calculated from the 95% UCL on the true population mean for each radionuclide and the total COCs does not exceed 15 mrem/yr above background levels, then the overburden/layback/concrete debris may be used to backfill the shallow zone of the site.
5	For soil samples collected from the deep zone of a remediation site: If the predicted concentration in the groundwater, modeled from concentrations representing the 95% UCL on the true population mean for each inorganic and radionuclide COC is less than the RAO for each COC, then the deep zone of the site will be designated as remedied and site closeout can proceed.
6	For samples of overburden/layback and concrete debris: If the predicted concentration in the groundwater modeled from concentrations representing the 95% UCL on the true population mean for each inorganic and radionuclide COC is less than the RAO for each COC, then the overburden/layback/borrow pit soil and concrete debris may be used to backfill the deep zone of the remediation site.
7	For samples collected from the nonradioactive sites pipelines: If the concentration representing the 95% UCL on the true population mean for each inorganic COC does not exceed the MTCA Method B cleanup level for that inorganic, no inorganic COC concentration exceeds twice the MTCA Method B cleanup level, no more than 10% of the inorganic COC concentrations exceed the MTCA Method B cleanup level, total hazard index is less than one, and total excess cancer risk is less than one in 100,000, then the pipelines will be designated as clean and they do not need to be removed.
8	For soil samples collected from the shallow zone of a 10-m (30-ft) transition zone beyond the first dam: If the concentration representing the 95% UCL on the true population mean for each inorganic COC does not exceed the MTCA Method B cleanup level for that inorganic, no inorganic COC concentration exceeds twice the MTCA Method B cleanup level, no more than 10% of the inorganic COC concentrations exceed the MTCA Method B cleanup level, total hazard index is less than one, total excess cancer risk is less than one in 100,000, and the dose rate calculated from the 95% UCL on the true population mean for each radionuclide and the total COCs does not exceed 15 mrem/yr above background levels, then the shallow zone of the site will be designated as remedied and the remainder of the trench will not be remediated.

6.0 STEP 6 – SPECIFY TOLERABLE LIMITS ON DECISION ERRORS

6.1 PURPOSE

The purpose of DQO Step 6 is to develop tolerable error limits. The probability of making an erroneous decision will be acceptable if it is within these limits. The error limits established in this step will be used to estimate the number of samples and to establish performance goals for the newly collected data.

One of the primary objectives that must be accomplished in DQO Step 6 is to choose between a statistical or judgmental sample design. Sampling designs may be based on statistics or professional judgment; neither approach is deemed to be absolutely correct. The choice between the two designs depends on the project task objectives, existing data, actions to be taken, and the severity of the consequences of making decision errors.

6.2 WORKSHEETS FOR STEP 6 -- SPECIFY TOLERABLE LIMITS ON DECISION ERROR

Table 6-1 outlines the severity of the consequences of each alternative action developed in DQO Steps 2 and 4.

Table 6-1. DQO Steps 2 and 4 Consequences Severity Summary. (2 pages)

DQO Step	PSQ #	AA #	Consequences Severity	Preliminary DQO Step 6 Sample Design Basis
Step 2	1	1	Moderate	Judgmental
		2	Low	
	2	2	Moderate	Statistical
		2	Low	
	3	1	Severe	Statistical
		2	Low	
	4	1	Severe	Statistical
		2	Low	
	5	1	Low	Judgmental
		2	Low	
	6	1	Moderate	Judgmental
		2	Low	
	7	1	Severe	Statistical
		2	Low	

Table 6-1. DQO Steps 2 and 4 Consequences Severity Summary. (2 pages)

DQO Step	PSQ #	AA #	Consequence Severity	Preliminary DQO Step 6: Sample Design Basis
Step 4	1	---	Not severe	Judgmental
	2	---	Not severe	Statistical
	3	---	Severe	Statistical
	4	---	Severe	Statistical
	5	---	Not severe	Judgmental
	6	---	Not severe	Judgmental
	7	---	Severe	Statistical

Table 6-2 identifies the range of values for the COCs.

Table 6-2. COC Range Values. (2 pages)

WS #	Media	COC	Range	
			Lower Limit	Upper Limit
		Radionuclides (pCi/g)		
1, 2 and 3	Soil	Americium-241[a]	0	44,700
		Cesium-137[a]	0	429,000
		Cobalt-60[a]	0	2,754,000
		Europium-154[b]	0	170,000
		Europium-155[b]	0	4,120
		Nickel-63	0	---
		Plutonium-239/240[a]	0	52,200
		Strontium-90[a]	0	132,000
		Tritium	0	---
		Inorganics (mg/kg)		
		Chromium (total)[b]	0	57.7
		Chromium (VI)	0	---
		Mercury	0	---
		Nitrate	0	---
		Inorganics (mg/kg)		
		pH (pH units)	---	---

Table 6-2. COC Range Values. (2 pages)

WSC	Media	COCs	Range	
			Lower Limit	Upper Limit
		Inorganics (mg/kg)		
4	Soil[b]	Antimony	3.4	12.7
		Arsenic	0.46	2.9
		Barium	41.5	93.7
		Beryllium	16.8	93.7
		Cadmium	0.2	1.48
		Chromium	2.8	14.6
		Copper	5.2	30.6
		Lead	1.5	6.4
		Manganese	73.8	702
		Mercury	0.12	0.27
		Nickel	3.6	15.5
		Selenium	0.42	2.5
		Silver	0.5	2.5
		Thallium	0.29	0.63
		Vanadium	6.6	81.1
		Zinc	13.6	94.4
		pH (pH units)	5.6	9.8
		Sulfate	6	130

[a] Values taken from BHI (1999c).
[b] Values taken from DOE-RL (1998a).

Figure 6-1 provides a flow diagram outlining the preliminary determination of the need for a statistically based or professional judgment-based sample design.

Figure 6-1. Preliminary Determination of the Need for a Statistically Based or Professional Judgment-Based Sample Design.

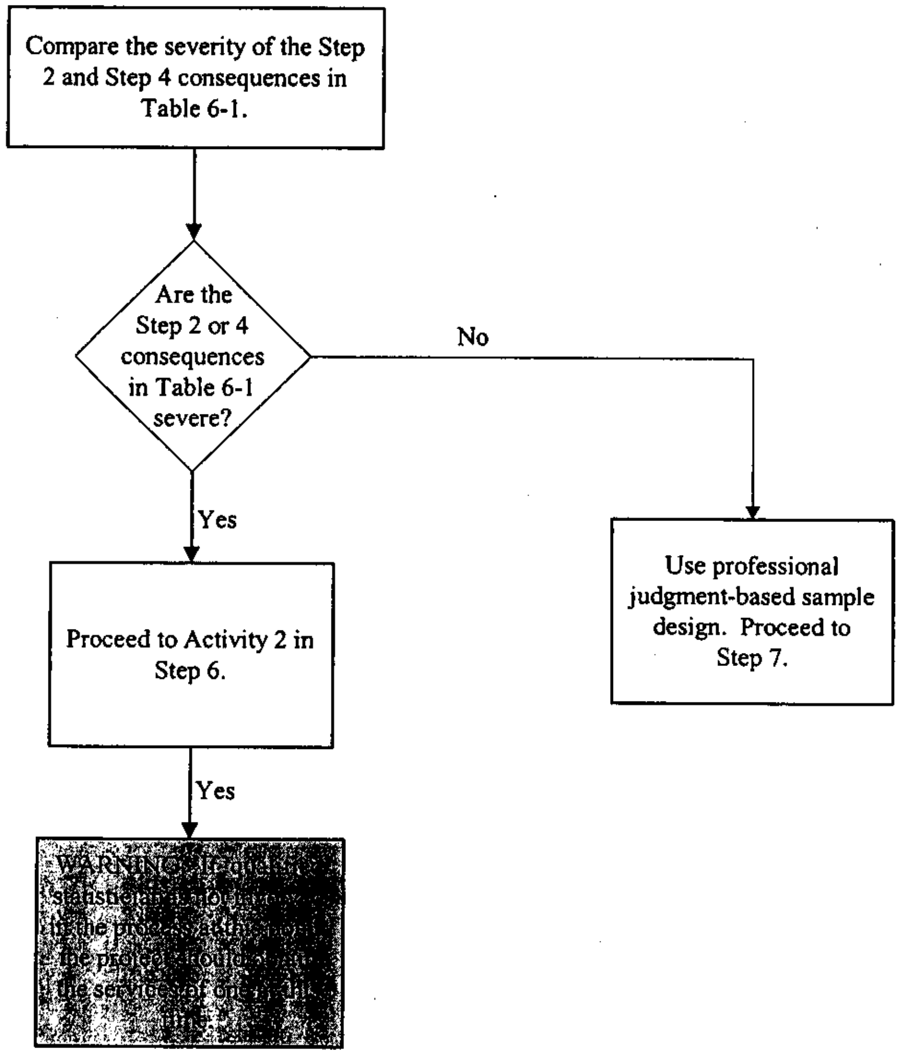


Table 6-3 provides a general statement of the null hypothesis and a specific null hypothesis for each decision statement.

Table 6-3. Statement of the Null Hypothesis (H_o).

The waste sites contain contaminants at concentrations that exceed cleanup levels or disposal waste acceptance criteria.

H_o for DS #1: The excavated contaminated soil/debris from radioactive sites (116-N-1, 116-N-3, and UPR-100-N-31) exceeds ERDF waste acceptance criteria.

H_o for DS #2: The debris from nonradioactive sites (120-N-1, 120-N-2, and 100-N-58) exceeds requirements for disposal in onsite inert/demolition waste landfills.

H_o for DS #3: The soils remaining after remediation exceed site cleanup criteria identified in the interim remedial action ROD or CMS/closure plan (120-N-1, 120-N-2, and 100-N-58).

H_o for DS #4: The contamination levels of overburden and layback soil exceed the criteria identified in the interim remedial action ROD for use as backfill.

H_o for DS #5: The contamination levels of borrow pit soils exceed criteria for use as backfill.

H_o for DS #6: The contamination levels in pipelines associated with nonradioactive sites (120-N-1, 120-N-2, and 100-N-58) exceed site criteria identified in the CMS/closure plan for being left in place.

H_o for DS #7: The soils in the transition zone near the first dam exceed site cleanup criteria identified in the interim remedial action ROD.

The action levels for the COCs identified for each decision statement are listed in Table 6-4.

Table 6-4. Action Level for the Decision. (3 pages)

DS	COCs	Action Level
	Radionuclides (pCi/g)	
1	Americium-241	25,500
	Cesium-137	16,300,000
	Cobalt-60	No limit
	Europium-154	No limit
	Europium-155	No limit
	Nickel-63	3.57E+08
	Plutonium-239/240	14,000
	Strontium-90	3.6E+09
	Tritium	No limit
	Metals (mg/kg)	
	Chromium (total)	59,000
	Mercury	No limit
	Nitrate	No limit

Table 6-4. Action Level for the Decision. (3 pages)

DS	COC	Action Level		
	TCLP (mg/L)			
	Arsenic	5		
	Barium	100		
	Cadmium	1		
	Chromium (total)	5		
	Lead	5		
	Selenium	1		
	Silver	5		
	Mercury	0.2		
2	Inorganic			
	pH (pH units)	<2 or >12.5		
	TCLP (mg/L)			
	Antimony	32		
	Arsenic	5		
	Barium	100		
	Beryllium	400		
	Cadmium	1		
	Chromium (total)	5		
	Copper	2,960		
	Lead	5		
	Manganese	11,200		
	Mercury	0.2		
	Nickel	1,600		
	Selenium	1		
	Silver	5		
	Thallium	6		
	Vanadium	560		
	Zinc	24,000		
3, 4, and 7	Radionuclides			
	A maximum dose of 15 mrem/yr above background (direct exposure), and 4 mrem/yr[a] (groundwater protection), calculated using RESRAD.			
	COC	Soil 0 to 15 ft bgs for Surface Exposure	Subsurface Soil >15 ft bgs for Groundwater/River Protection	Action Level (Based on More Restrictive Requirement)
	Inorganics (mg/kg)			
	Chromium (III)	80,000	[b]	80,000
	Chromium (VI)	400	2	2
	Mercury	24	[b]	24
	Nitrate	N/A	4,400	4,400

Table 6-4. Action Level for the Decision. (3 pages)

[illegible]	[illegible]	[illegible]
	[illegible]	
5	Surveyed per radiation control procedures.	
	[illegible]	[illegible]
		[illegible]
3 (non-radiological sites) and 6	Arsenic	20
	Barium	5,600
	Cadmium	80
	Chromium (III)	80,000
	Chromium (VI)	400
	Lead	353
	Mercury	24
	Selenium	400
	Silver	400
	pH (pH units)	<2 or >12.5
	Sulfate	25,000

[a] The 4 mrem/yr dose is based on target organ protection from the consumption of groundwater as calculated by the NBS Handbook 69 methodology (NBS 1963).

[b] The RESRAD unit gradient model predicts the contaminant will not reach groundwater within 1,000-year time frame.

N/A = not applicable

Table 6-5 identifies the decision error statements. Decisions in this project fall into three basic categories: (1) decisions regarding acceptance criteria for disposal (in the ERDF or in an onsite inert/demolition landfill), (2) cleanup decisions (allowing remediation to stop), and (2) decisions regarding whether materials can be used as backfill.

Table 6-5. Decision Error Statements. (2 pages)

[illegible]	Definition
<u>False-positive decision error</u> -- The false-positive decision error occurs when the null hypothesis is rejected when it is true. A statistician refers to a false-positive error as a "Type I error." The measure of the size of the error is called the alpha (α), the level of significance, or the size of the critical region. <u>False-negative decision error</u> -- The false-negative decision error arises when the decision-maker fails to reject the null hypothesis when it is false. A statistician usually refers to a false-negative error as a "Type II error." The measure of the size of the error is called beta (β), and is also known as the complement of the *power* of a hypothesis test.	
[illegible]	
False-positive	Incorrectly deciding that contaminated materials do not exceed disposal criteria and incorrectly sending the materials to the ERDF, etc.
False-negative	Incorrectly deciding that contaminated materials do exceed disposal criteria and unnecessarily exploring alternative disposal options.

Table 6-5. Decision Error Statements. (2 pages)

Decision Error	Definition
Cleanup Decisions (DS #3, #6, and #7)	
False-positive	Incorrectly deciding to end remediation efforts.
False-negative	Incorrectly deciding that remediation efforts must continue.
Backfill Decisions (DS #4 and #5)	
False-positive	Incorrectly deciding that contaminated overburden/layback soil and/or concrete debris can be used as backfill.
False-negative	Incorrectly deciding that uncontaminated overburden/layback soil and/or concrete debris must be disposed of as contaminated waste.

The worst-case decision errors are identified in Table 6-6.

Table 6-6. Worst-Case Decision Error Determination.

Decision Error	Severity of Decision Error Near the Action Level
Type I: Incorrectly deciding to end remediation efforts.	Severe
Type II: Incorrectly deciding that remediation efforts must continue.	Moderate
Type I: Incorrectly deciding that contaminated overburden/layback soil can be used as backfill.	Severe
Type II: Incorrectly deciding that uncontaminated overburden/layback soil must be disposed of as contaminated waste.	Moderate
Type I: Incorrectly deciding that contaminated materials do not exceed disposal criteria and incorrectly sending them to the ERDF, etc.	Moderate
Type II: Incorrectly deciding that contaminated materials do exceed disposal criteria and unnecessarily exploring alternative disposal options.	Low

Potential consequences of decision errors are listed in Table 6-7.

Table 6-7. Potential Consequences of Decision Errors.

Type of Decision Error	Impact	Potential Consequences
False-positive: Incorrectly deciding to end remediation efforts.	Human health risks, and political and legal ramifications	Severe
False-negative: Incorrectly deciding that remediation efforts must continue.	Economic costs	Moderate
False-positive: Incorrectly deciding that contaminated overburden/ layback soil and/or concrete debris can be used as backfill.	Human health and ecological risks, and political and legal ramifications	Severe
False-negative: Incorrectly deciding that uncontaminated overburden/ layback soil and/or concrete debris must be disposed of as contaminated waste.	Economic costs	Moderate
Incorrectly deciding that contaminated materials do not exceed disposal criteria and incorrectly sending the materials to the ERDF, etc.	Human health risks, and political and legal ramifications	Moderate
Incorrectly deciding that contaminated materials do exceed disposal criteria and unnecessarily exploring alternative disposal options.	Human health and ecological risks, and political and legal ramifications	Low

Figure 6-2 provides a flowchart on the determination of the need for a statistically based or professional judgment-based sample design.

Figure 6-2. Determination of the Need for a Statistically Based or Professional Judgment-Based Sample Design.

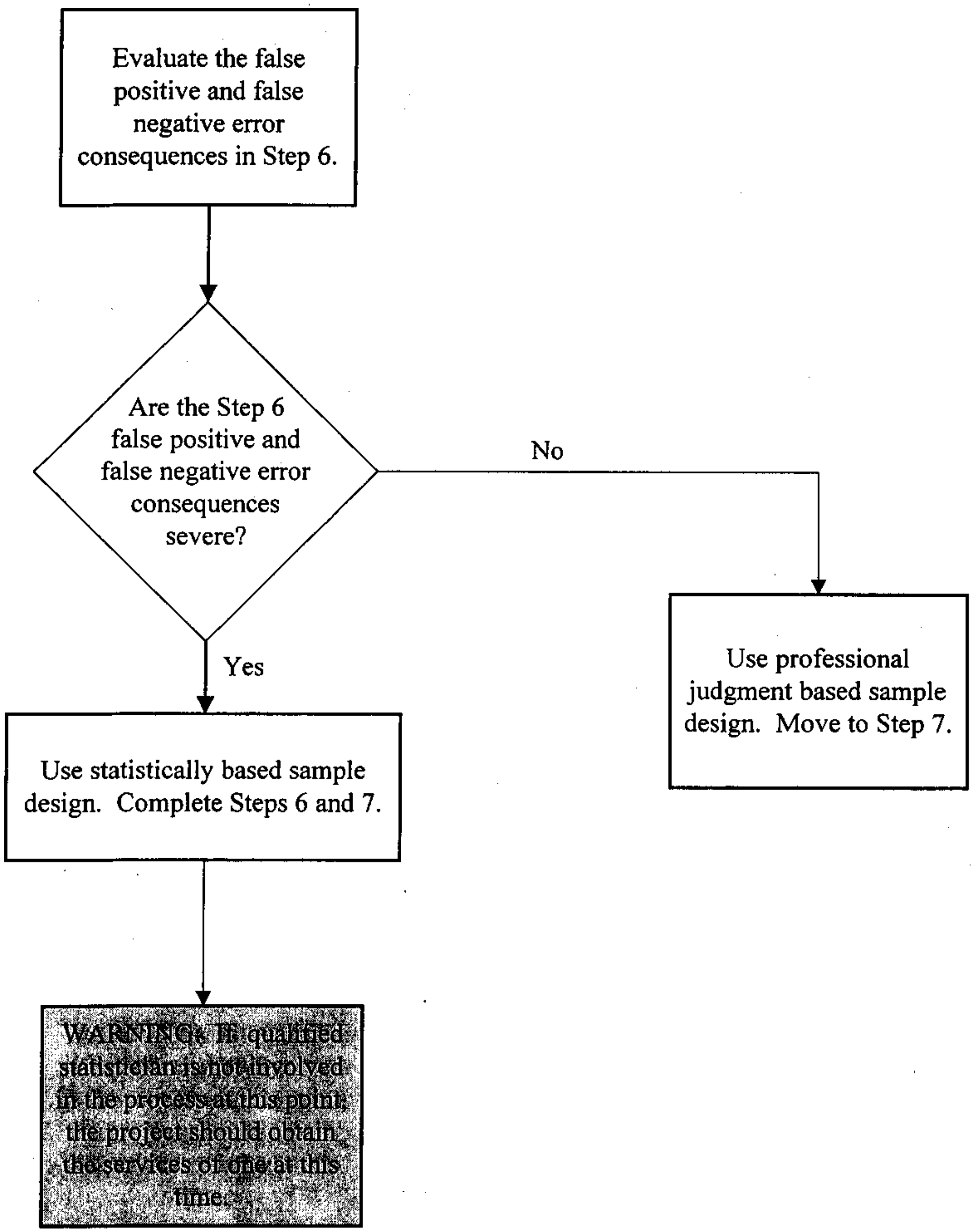


Table 6-8 provides a definition of the gray region, which applies to all decision statements.

Table 6-8. Gray Region Definition.

Between the action level and 80% of the action level for each COC.

For each COC and each statistical test of interest, tolerable levels of decision error (the largest decision error factors that can tolerated and still resolve the decision statements) are provided for the positive and negative zones and the gray region. Table 6-9 contains the tolerable decision errors.

For all cleanup and disposal decisions (DS #3 through #7), the following apply:

- The statistical test of interest is a one-tailed 95% upper confidence limit (UCL)
- The false-positive (α) error rate is 5%
- The false-negative (β) error rate is 20%
- The lower bound of the gray region is 80% of the corresponding action level.

Table 6-9. Tolerable Decision Errors. (2 pages)

DS	Media	COC	Test Statistic of Interest	Range		Tolerable Decision Error	
						False Positive (α)	False Negative (β)
2	Debris that contacted liquid effluents from the 120-N-1, 120-N-2, and 100-N-58 percolation pond system	*Inorganics*					
		pH (pH units)	Sample mean	2	12.5	5	20
		TCLP (mg/L)					
		Arsenic	Sample mean	0	5	5	20
		Barium		0	100	5	20
		Cadmium		0	1	5	20
		Chromium (total)		0	5	5	20
		Lead		0	5	5	20
		Mercury		0	0.2	5	20
		Selenium		0	1	5	20
		Silver		0	5	5	20
3, 4, and 7	Remaining soil; and/or overburden/ layback soil for use as backfill in the shallow zone, radiological sites	*Radioisotopes (pCi/g)*					
		Americium-241	95% UCL estimate of the true population mean, calculated from the sampling data	0	41.6	5	20
		Cesium-137		0	6.1	5	20
		Cobalt-60		0	1.4	5	20
		Europium-154		0	3.1	5	20
		Europium-155		0	127	5	20
		Nickel-63		0	4,031	5	20
		Plutonium-239/240		0	23.5	5	20
		Strontium-90		0	3.7	5	20
		Tritium		0	241	5	20

Table 6-9. Tolerable Decision Errors. (2 pages)

DS	Media	COCs	Test Statistic of Interest	Range[a]		Tolerable Decision Error: False Positives (%)	Tolerable Decision Error: False Negatives (%)
3 and 6	Soil and pipe scale from the 120-N-1, 120-N-2, and 100-N-58 percolation system	**Inorganics (mg/kg)**					
		Chromium (VI)	95% UCL estimate of the true population mean, calculated from the sampling data	0	400	5	20
		Mercury		0	24	5	20
		Nitrate		0	4,400	5	20
		Inorganics (mg/kg)					
		Antimony	95% UCL estimate of the true population mean, calculated from the sampling data	0	32	5	20
		Arsenic		0	20[c]	5	20
		Barium		0	5,600	5	20
		Beryllium		0	400	5	20
		Cadmium		0	80	5	20
		Chromium (III)		0	80,000	5	20
		Chromium (VI)		0	400	5	20
		Copper		0	2,960	5	20
		Lead		0	353	5	20
		Manganese		0	11,200	5	20
		Mercury		0	24	5	20
		Nickel		0	1,600	5	20
		Nitrate		0	4,400	5	20
		Selenium		0	400	5	20
		Silver		0	400	5	20
		Thallium		0	6	5	20
		Sulfate		0	25,00	5	20
		Vanadium		0	560	5	20
		Zinc		0	24,000	5	20
		pH (pH units)		2	12.5	5	20

[a] Upper end of range taken to be the concentration representing 15 mrem/yr limit for each radionuclide alone or the cleanup standard for nonradionuclides.

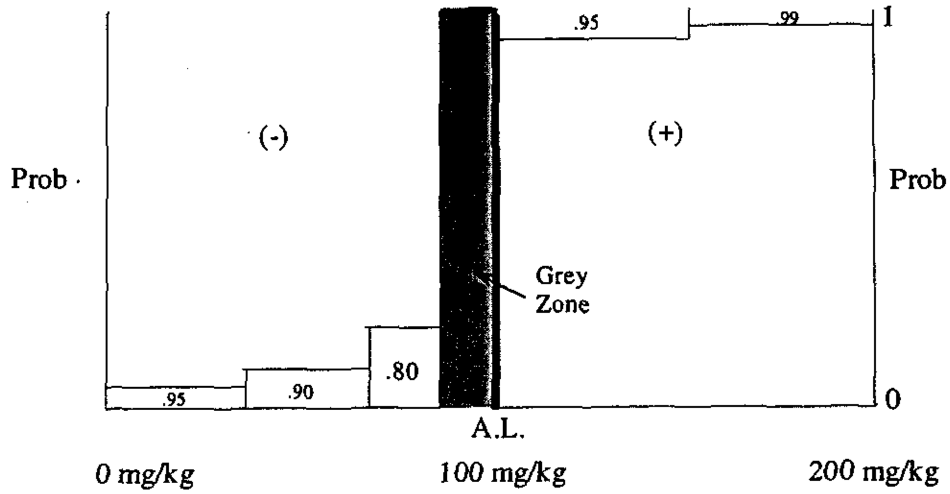
The boundaries of the gray region are shown in Table 6-10.

Table 6-10. Boundaries of the Gray Region.

Media	COCs	Gray Region Boundaries
All	All	80% of action level to 100% of action level

Figure 6-3 provides a graph of the true value of the parameter.

Figure 6-3. Graph of True Value of the Parameter.



7.0 STEP 7 – OPTIMIZE THE DESIGN

7.1 PURPOSE

The purpose of DQO Step 7 is to identify the most resource-effective design while not exceeding the tolerable false-positive and false-negative decision error rates (which were specified in DQO Step 6 for generating data to support decisions), while maintaining the desired degree of precision and accuracy. Table 7-1 identifies the data collection design determination.

Table 7-1. Data Collection Design Determination. (2 pages)

Decision	Statistical	Non-Statistical	Rationale
1. Determine if excavated contaminated soil/debris from radioactive sites (116-N-1, 116-N-3, and UPR-100-N-31) meets ERDF waste acceptance criteria and can be disposed in the ERDF or if alternate disposal options need to be considered.		X	Process knowledge and sampling data indicate that waste materials will not exceed ERDF waste acceptance criteria. Judgmental samples will be used to confirm the waste profile. **Note:** This data collection design is really a quasi-statistical design. Samples will be taken systematically (as opposed to judgmentally), because every excavator bucket will be screened for gamma activity to ensure that safety requirements are met. If a given bucket exceeds the safety limits, then the contents will be returned to the trench or crib, remixed with other materials, and re-screened until the contents of the bucket pass the safety requirements. Because every bucket is below the safety requirement, the average of the buckets will also be below the safety limit. Although the 95% UCL will not be formally calculated, it is reasonable to assume that since a large number of buckets will be screened, the 95% UCL will be very close to the mean, which will be below the safety limits. Using the measured gamma activity as the basis, the percent of profile for ERDF waste acceptance COCs will be estimated.
2. Determine if debris from nonradioactive sites (120-N-1, 120-N-2, and 100-N-58) meets requirements for disposal in onsite inert/demolition waste landfills or if alternate disposal options need to be considered.	X		Process knowledge and sampling data indicate that waste debris materials will not exceed the levels for disposal in onsite inert/demolition landfills.
3. Determine if soils remaining after remediation exceed site cleanup criteria identified in the interim remedial action ROD or CMS/closure plan and require additional remediation or if remedial action is complete.	X		The MTCA rules for site closeout require a statistically based sample design.

Table 7-1. Data Collection Design Determination. (2 pages)

Decision	Statistical	Non-Statistical	Rationale
4. Determine if contamination levels of overburden and layback soil exceed site criteria identified in the interim remedial action ROD meet criteria for backfill or if the soil must be disposed in the ERDF.	X		The MTCA rules for site closeout require a statistically based sample design.
5. Determine if contamination levels of borrow pit soil meet site criteria identified in the interim remedial action ROD for use as backfill or if alternate backfill material must be used.		X	Process knowledge/history indicates that borrow pits have never been exposed to radioactive or chemical contaminants.
6. Determine if contamination levels in pipelines associated with nonradioactive sites (120-N-1, 120-N-2, and 100-N-58) meet site criteria identified in the CMS/closure plan for being left in place or if the pipelines must be removed and disposed appropriately (ERDF or inert/demolition waste landfill).		X	The MTCA rules for site closeout require a statistically based sample design. However, access constraints on the pipeline make a statistically based design very difficult and expensive to implement. Process history and sampling results from the settling ponds indicate that the sites are clean, so by inference, the pipelines have a high probability of being clean.
7. Determine if soils in the transition zone near the first dam of the 116-N-3 Trench exceed site cleanup criteria identified in the CMS/closure plan and additional remediation is needed or if remedial action is complete up to this transition zone.	X		The transition zone must meet the same closeout requirements as the remediated portion of the 116-N-3 Trench (see decision #3). The MTCA rules for site closeout require a statistically based sample design.

The data collection design alternatives are identified in Table 7-2.

Table 7-2. Data Collection Design Alternatives.

Decision	Statistical	Judgmental
1. Determine if excavated contaminated soil/debris from radioactive sites (116-N-1, 116-N-3, and UPR-100-N-31) meets ERDF waste acceptance criteria and can be disposed in the ERDF or if alternate disposal options need to be considered.		X
5. Determine if contamination levels of borrow pit soil meet site criteria identified in the interim remedial action ROD for use as backfill or if alternate backfill material must be used.		X
6. Determine if contamination levels in pipelines associated with nonradioactive sites (120-N-1, 120-N-2, and 100-N-58) meet site criteria identified in the CMS/closure plan for being left in place or if the pipelines must be removed and disposed appropriately (ERDF or inert/demolition waste landfill).		X

If the data collection design for a given decision will be statistical, determine what type of statistical design is appropriate. State the null hypothesis that will be tested after the data are collected. The null hypothesis includes the statistical characteristic of interest, the action level, and the relationship between them.

The types of statistical designs generally used in environmental problems include the following:

- Simple random
- Stratified random
- Sequential
- Systematic
- Geostatistical
- Factorial.

Table 7-3 identifies the statistical design determination.

Table 7-3. Statistical Design Determination. (2 pages)

Decision	Type of Statistical Design	Null Hypothesis and Alternate
2. Determine if debris from nonradioactive sites (120-N-1, 120-N-2, and 100-N-58) meets requirements for disposal in onsite inert/demolition waste landfills or if alternate disposal options need to be considered.	Random sampling	H_o for DS #2: The debris exceeds criteria for disposal in inert/demolition waste landfills.
3. Determine if soils remaining after remediation exceed site cleanup criteria identified in the interim remedial action ROD or CMS/closure plan and require additional remediation or if remedial action is complete.	Random sampling	H_o for DS #3: The soils remaining after remediation exceed site cleanup criteria identified in the interim remedial action ROD or CMS/closure plan.

Table 7-3. Statistical Design Determination. (2 pages)

Decision	Type of Statistical Design	Null Hypothesis of Interest
4. Determine if contamination levels of overburden and layback soil exceed site criteria identified in the interim remedial action ROD for meet criteria for if backfill or must be disposed in ERDF.	Random sampling	H_o for DS #4: The contaminated levels of overburden and layback soil exceed the criteria identified in the interim remedial action ROD for use as backfill.
7. Determine if soils in the transition zone near the first dam of the 116-N-3 Trench exceed site cleanup criteria identified in the interim remedial action ROD and additional remediation is needed, or determine if remedial action is complete up to this transition zone.	Random sampling	H_o for DS #7: The soils in the transition zone exceed site cleanup criteria identified in the interim remedial action ROD.

Table 7-4 and 7-4a further describe the strategy for each decision statement.

Table 7-4. Sampling Strategies. (6 pages)

DS #	Decision Statement	WS #	Geographical Area of Interest	Strata	Rationale	Data and Decision Type	Sampling, Measurement Design (See Table 7-3b)	Number of Measurements To Be Taken
1	Determine if excavated contaminated soil/debris from radioactive sites (116-N-1, 116-N-3 and UPR-100-N-31) meets ERDF waste acceptance criteria and can be disposed in the ERDF or if alternate disposal options need to be considered.	1	116-N-1 Crib and associated pipelines	Layer of contaminated boulders and cobbles	Boulders and cobbles have much lower surface area to volume ratio than underlying soils. If underlying soils meet ERDF waste acceptance criteria, boulders and cobbles will also meet the waste acceptance criteria. Excavated materials will be screened on bucket-by-bucket basis for health and safety. This screening, correlated with analytical laboratory results, is sufficient to satisfy ERDF waste acceptance criteria.	Field screening data with judgmental decision	Design A: boulders, cobble, small debris, and contaminated soil	20% of buckets, as directed by resident engineer
				Contaminated native soil	Excavated materials will be screened on bucket-by-bucket basis for health and safety. This screening, correlated with analytical laboratory results, is sufficient to satisfy ERDF waste acceptance criteria.	Field screening data with judgmental decision	Design A: boulders, cobble, small debris, and contaminated soil	20% of buckets, as directed by resident engineer
				Contaminated pipelines/ debris	Pipelines and debris have much lower surface area to volume ratio than underlying soils. If underlying soils meet ERDF waste acceptance criteria, pipes and debris will also meet the waste acceptance criteria.	Field screening data with judgmental decision	Design A: boulders, cobble, small debris, and contaminated soil	20% of buckets, as directed by resident engineer

Table 7-4. Sampling Strategies. (6 pages)

DS #	Decision Statement	WS #	Geographical Area of Interest	Strata	Rationale	Data and Decision Type	Sampling/Measurement Design (See Table 7-3b)	Number of Measurements To Be Taken
			UPR-100-N-31	Contaminated native soil	Excavated materials will be screened on bucket-by-bucket basis for health and safety. This screening, correlated with analytical laboratory results is sufficient to satisfy ERDF waste acceptance criteria.	Field screening data with judgmental decision	Design A: boulders, cobble, small debris, and contaminated soil	20% of buckets, as directed by resident engineer
		2	116-N-1 Trench and cover panels	Cover panels/telephone poles (rubblized)	Cover panels have much lower surface area to volume ratio than underlying soils. If underlying soils meet ERDF waste acceptance criteria, cover panels will also meet the waste acceptance criteria.	Field screening data with judgmental decision	Design A: boulders, cobble, small debris, and contaminated soil	20% of buckets, as directed by resident engineer
				Contaminated native soil	Excavated materials will be screened on bucket-by-bucket basis for health and safety. This screening, correlated with analytical laboratory results, is sufficient to satisfy ERDF waste acceptance criteria.	Field screening data with judgmental decision	Design A: boulders, cobble, small debris, and contaminated soil	20% of buckets, as directed by resident engineer
		3	116-N-3 Crib and Trench, cover panels, and associated pipelines	Cover panels (rubblized)	Cover panels have much lower surface area to volume ratio than underlying soils. If underlying soils meet ERDF waste acceptance criteria, cover panels will also meet the waste acceptance criteria.	Field screening data with judgmental decision	Design A: boulders, cobble, small debris, and contaminated soil	20% of buckets, as directed by resident engineer
				Cover panels (removed intact)	Cover panels have much lower surface area to volume ratio than underlying soils. If underlying soils meet ERDF waste acceptance criteria, cover panels will also meet the waste acceptance criteria.	Field screening data with judgmental decision	Design B: 116-N-3 Crib cover panels	Approx. 10% of removed sections with a minimum of 30 surveys

Table 7-4. Sampling Strategies. (6 pages)

DS #	Decision Statement	WS	Geographical Area of Interest	Strata	Rationale	Data and Decision Type	Sampling Measurement Design (See Table 7-3b)	Number of Measurements To Be Taken
				Contaminated native soil	Excavated materials will be screened on bucket-by-bucket basis for health and safety. This screening, correlated with analytical laboratory results, is sufficient to satisfy ERDF waste acceptance criteria.	Field screening data with judgmental decision	Design A: boulders, cobble, small debris, and contaminated soil	20% of buckets, as directed by resident engineer
				Contaminated pipelines/ debris	Pipelines and debris have much lower *surface area to volume ratio than* underlying soils. If underlying soils meet ERDF waste acceptance criteria, pipelines and debris will also meet the *waste acceptance criteria.*	Field screening data with judgmental decision	Design A: boulders, cobble, small debris, and contaminated soil	20% of buckets, as directed by resident engineer
				Grouted main trough	Trough has much lower surface area to volume ratio than underlying soils. If underlying soils meet ERDF waste acceptance criteria, trough will also meet the waste acceptance criteria.	Field screening data with judgmental decision	Design C: grouted main *trough, 116-N-3 Crib*	Surveyed per radiological control requirements
2	Determine if debris from nonradioactive sites (120-N-1, 120-N-2, and 100-N-58) meets requirements for disposal in onsite inert/demolition waste landfills or if alternate disposal options need to be considered.	4	120-N-1, 120-N-2, 100-N-58, and associated pipelines	Liner	*Dangerous waste determination* based on analytical laboratory results of samples.	Random sampling and statistical decision	Design D: 120-N-1, 120-N-2, and 100-N-58 debris waste designation	Two samples for TCLP analysis
				Pipelines (if they need to be removed)	Dangerous waste determination based on analytical laboratory results of samples.	Random sampling and statistical decision	Design D: 120-N-1, 120-N-2, and 100-N-58 debris waste designation	Two samples for TCLP analysis
				Debris	Dangerous waste determination based on analytical laboratory results of samples.	Random sampling and statistical decision	Design D: 120-N-1, 120-N-2, and 100-N-58 debris waste designation	Two samples for TCLP analysis of each debris type that would have contacted the wastewater (e.g., the sample shed structure [walls, structural steel, roof, etc.] and fencing need not be sampled because they did not contact the wastewater)

Table 7-4. Sampling Strategies. (6 pages)

DS #	Decision Statement	WS #	Geographical Area of Interest	Strata	Rationale	Data and Decision Type	Sampling Measurement Design (See Table 7-3b)	Number of Measurements To Be Taken
3	Determine if soils remaining after remediation exceed site cleanup criteria identified in the interim remedial action ROD and require additional remediation or if remedial action is complete.	1	116-N-1 Crib and associated pipelines	Surface soil remaining after excavation	Analytical laboratory results, RESRAD analysis of data to determine if remediated site presents a direct exposure threat.	Random sampling and statistical decision	Design E1: 116-N-1 surface soil closeout	To be calculated, with a minimum of 10 samples
				Subsurface soil remaining after excavation	Analytical laboratory results, RESRAD analysis of data to determine if remediated site presents a direct exposure/groundwater protection threat.	Random sampling and statistical decision	Design E2: 116-N-1 subsurface soils and overburden/layback	To be calculated, with a minimum of 10 samples
			UPR-100-N-31	Surface soil remaining after excavation	Analytical laboratory results, RESRAD analysis of data to determine if remediated site presents a direct exposure threat.	Random sampling and statistical decision	Design E1: 116-N-1 surface soil closeout	To be calculated, with a minimum of 10 samples
				Subsurface soil remaining after excavation	Analytical laboratory results, RESRAD analysis of data to determine if remediated site presents a direct exposure/groundwater protection threat.	Random sampling and statistical decision	Design E2: 116-N-1 subsurface soils and overburden/layback	To be calculated based on variance to be used at 116-N-1 with a minimum of 10 samples
		2	116-N-1 Trench and cover panels	Surface soil remaining after excavation	Analytical laboratory results, RESRAD analysis of data to determine if remediated site presents a direct exposure threat.	Random sampling and statistical decision	Design E1: 116-N-1 surface soil closeout	To be calculated, with a minimum of 10 samples
				Subsurface soil remaining after excavation	Analytical laboratory results, RESRAD analysis of data to determine if remediated site presents a direct exposure/groundwater protection threat.	Random sampling and statistical decision	Design E2: 116-N-1 subsurface soils and overburden/layback	To be calculated, with a minimum of 10 samples

Table 7-4. Sampling Strategies. (6 pages)

DS #	Decision Statement	WS #	Geographical Area of Interest	Strata	Rationale	Data and Decision Type	Sampling Measurement Design (See Table 7-3b)	Number of Measurements To Be Taken
		3	116-N-3 Crib and Trench, cover panels, and associated pipelines (upstream of the first dam)	Surface soil remaining after excavation	Analytical laboratory results, RESRAD analysis of data to determine if remediated site presents a direct exposure threat.	Random sampling and statistical decision	Design E3: 116-N-3 surface soils	To be calculated, with a minimum of 10 samples
				Subsurface soil remaining after excavation	Analytical laboratory results, RESRAD analysis of data to determine if remediated site presents a direct exposure/groundwater protection threat.	Random sampling and statistical decision	Design E4: 116-N-3 subsurface soils and overburden/layback	To be calculated, with a minimum of 10 samples
		4	120-N-1, 120-N-2, 100-N-58, and associated pipelines	Soil remaining at nonradioactive contaminated sites	Analytical laboratory results, comparison of data to MTCA Method B criteria determine if remediated site presents a threat.	Random sampling and statistical decision	Design F: 120-N-1, 120-N-2, and 100-N-58 site closeout	Two samples in the northeastern portion of the units
4	Determine if contamination levels of overburden and layback soil exceed site criteria identified in the interim remedial action ROD meet criteria for backfill or if the soil must be disposed in the ERDF.	1	116-N-1 Crib and associated pipelines	Overburden/ layback soils	Analytical laboratory results, RESRAD analysis of data to determine if remediated site presents a direct exposure/groundwater protection threat.	Random sampling and statistical decision	Design E2: 116-N-1 subsurface soils and overburden/layback	To be calculated, with a minimum of 10 samples
			UPR-100-N-31	Overburden/ layback soils	Analytical laboratory results, RESRAD analysis of data to determine if remediated site presents a direct exposure/groundwater protection threat.	Random sampling and statistical decision	Design E1: 116-N-1 surface soil closeout.	To be calculated, with a minimum of 10 samples
		2	116-N-1 Trench and cover panels	Overburden/ layback soils	Analytical laboratory results, RESRAD analysis of data to determine if remediated site presents a direct exposure/groundwater protection threat.	Random sampling and statistical decision	Design E2: 116-N-1 subsurface soils and overburden/layback	To be calculated, with a minimum of 10 samples
		3	116-N-3 Crib and Trench (upstream of the first dam), associated cover panels, and associated pipelines	Overburden/ layback soils	Analytical laboratory results, RESRAD analysis of data to determine if remediated site presents a direct exposure/groundwater protection threat.	Systematic sampling and statistical decision	Design E4: 116-N-3 subsurface soils and overburden/layback	Ten or more, as required by process

Table 7-4. Sampling Strategies. (6 pages)

DS #	Decision Statement	WS #	Geographical Area of Interest	Strata	Rationale	Data and Decision Type	Sampling Measurement Design (See Table 7-5b)	Number of Measurements To Be Taken
5	Determine if contamination levels of borrow pit soil meet site criteria for use as backfill or if alternate backfill material must be used.	1, 2, 3, and 4	116-N-1, 116-N-3, UPR-100-N-31, 120-N-1, 120-N-2, 100-N-58 Crib, and associated pipelines	Borrow pit soil	Process knowledge and field screening.	Field screening with judgmental decision	Based on radiation control practices and procedures	A minimum of 10 % of the surface area of the borrow pit
6	Determine if contamination levels in pipelines associated with nonradioactive sites (120-N-1, 120-N-2, and 100-N-58) meet site criteria identified in CMS/closure plan for being left in place or if the pipelines must be removed and disposed appropriately (ERDF or inert/demolition waste landfill).	4	120-N-1, 120-N-2, 100-N-58, and associated pipelines	Pipelines	Comparison of analytical laboratory results with MTCA Method B limits from samples taken from the interior of the pipelines. Pipelines have very limited access.	Convenience sampling with judgmental decision	Design G: 120-N-1, 120-N-2, and 100-N-58 pipelines	Two samples, one from each end of the pipeline
7	Determine if soils in the transition zone near the first dam of the 116-N-3 Trench exceed site cleanup criteria identified in the interim remedial action ROD and additional remediation is needed or determine if remedial action is complete up to this transition zone.	3	116-N-3 Trench (downstream of the first dam) and associated cover panels	Subsurface soil remaining after caving in cover panels	Rather than surveying and sampling the entire length of the trench downstream of the first dam, a clean transition zone will be identified downstream of the first dam. It is reasonable to assume that if a clean transition zone can be identified and characterized, then all soils downstream of that transition zone will be clean as well.	Systematic sampling and statistical decision	Design H: transition zone downstream of first dam, 116-N-3 Trench	Twelve or more, as required by the process

Table 7-4a. Sampling Designs. (3 pages)

Design A: Boulders, cobbles, small debris, contaminated soil, and rubblized cover panels This design refers to materials small enough to fit into ERDF roll-on/roll-off containers. As excavation of the crib and trench proceeds, the contents of each excavator bucket (or section of debris, if too large to fit within an excavator bucket, but otherwise small enough to be placed in an ERDF roll-on/roll-off container) will be surveyed for gamma activity. The relationship between gamma activity and other isotopes of interest (primarily alpha emitters) will be used to ensure that ERDF safety requirements are met. If the gamma level and corresponding isotopic levels exceed safety limits, the bucket contents will be returned to the trench or crib. The percent of profile in the container will be calculated for each COC based on the same correlation of isotopes to the measured gamma activity.
Design B: 116-N- 3 Crib cover panels The 116-N-3 Crib cover panels may be removed intact and placed on a truck for transport to the ERDF. Historical process information indicates that the entire crib was flooded and it is, therefore, reasonable to assume that contamination of the crib covers will be relatively uniform. Initially each panel will be surveyed for removable and non-removable contamination. With experience, depending on the levels of contamination observed, the requirement for survey of every panel will be reduced. The percent of profile in the container will be calculated for each COC based on a correlation to the measured gamma activity.
Design C: Grouted main trough, 116-N-3 Crib The main trough of the 116-N-3 Crib will be filled with grout and then cut into large pieces, approximately 9.2-m (30-ft) long. Each of the trough sections will be surveyed per radiological control requirements.
Design D: 120-N-1, 120-N-2, and 100-N-58 debris waste designation Debris from the 120-N-1, 120-N-2, and 100-N-58 sites will be randomly sampled for dangerous waste determination. Data from previous sampling in the 120-N-1, 120-N-2, and 100-N-58 system (Appendix B of DOE-RL [1998a]) were determined to follow a lognormal distribution (Section B4.3.2 of DOE-RL [1998a]). Because the data are lognormally distributed and because the percentage of nondetects is between 15% and 50%, Cohen's adjustment (as described in Ecology [1993]) was used to obtain a more accurate estimate of the standard deviation of the data. Chromium was the analyte with a mean closest to the action level, and chromium was selected for this analysis (chromium had 32% nondetects). Cohen's adjusted variance (also in natural log units) is 0.251. Using Cohen's adjusted variance, the number of samples needed to have 95% confidence that the estimate of the median contained no more than 20%, 30%, or 100% relative error was calculated. For 100% relative error in the estimate of the median, two samples are needed to have 95% confidence that the sample median (i.e., the estimate of the population median) contains no more than 100% relative error. The 100% relative error was chosen because the maximum values of the data are significantly less than the regulatory limit (as specified in 40 CFR 261.24).

Table 7-4a. Sampling Designs. (3 pages)

Design E1: 116-N-1 surface soil closeout

Because the 116-N-1 Crib and Trench sites are analogous to the 116-N-3 Crib and Trench sites, the number of closeout surface soil samples calculated for the 116-N-3 site will also be used for the 116-N-1 site.

Design E2: 116-N-1 subsurface closeout

Because the 116-N-1 Crib and Trench sites are analogous to the 116-N-3 Crib and Trench sites, the number of closeout subsurface soil samples calculated for the 116-N-3 site will also be used for the 116-N-1 site.

Design E3: 116-N-3 surface soil closeout <u>and overburden/layback soils</u>

After contaminated soil and debris have been removed to a depth of 1.5 m (5 ft) below the bottom of the engineered structure, 30 sampling locations will be randomly selected on the bottom of the trench or crib. These 30 locations will be screened for gamma activity. Using this information, the population variances of the COCs will be estimated. From these, the largest variance estimate will be chosen and used to calculate the number of closeout samples needed. If the data are normally distributed and are not correlated, the t-test would be used to test the hypothesis and the following equation (EPA 1994b) may be used to calculate the minimum number of verification/closeout samples:

$$n_d = \sigma^2 \left\{ \frac{z_{1-\beta} + z_{1-\alpha}}{C_s - \mu_1} \right\}^2 + \frac{1}{2}(z_{1-\alpha})^2$$

where:

	σ	=	the standard deviation.
	$Z_{1-\alpha}$ and $Z_{1-\beta}$	=	the critical values for the normal distribution with probabilities of $1-\alpha$ and $1-\beta$, respectively (.95 and .80 for this calculation).
	C_s	=	the cleanup standard, which will be the limit in Table 5-3.
	μ_1	=	the true mean concentration (less than the cleanup standard value) where the probability is no greater than 0.20 of deciding the site does not meet the cleanup standard. In other words, μ_1 is the lower bound of the "gray region."

If the calculated number of samples is less than 10, then 10 samples will be collected.[a] If the calculated number of samples is greater or equal to 10, then the calculated number of samples will be collected. The locations for the closeout samples will be randomly determined by a process completely separate from the process used for choosing the locations of the variance samples. After collection and analysis, the 95% UCL limits of the COCs will be compared to the appropriate RAGs for surface soils. The RESRAD model will be used to calculate the mrem/yr dose above background, which will be compared to the limit of 15 mrem/yr above background. Chemical contaminant data will be evaluated per MTCA Method B criteria for the following: the concentration representing the 95% UCL on the true population mean for each inorganic COC does not exceed the MTCA Method B cleanup level for that inorganic, no inorganic COC concentration exceeds twice the MTCA Method B cleanup level, no more than 10% of the inorganic COC concentrations exceed MTCA Method B cleanup level, total hazard index is less than one total excess cancer risk is less than one in 100,000, and the dose rate calculated from the 95% UCL on the true population mean for each radionuclide and the total COCs does not exceed 15 mrem/yr above background levels, then the shallow zone of the site will be designated as remedied and site closeout can proceed.

Table 7-4a. Sampling Designs. (3 pages)

Design E4: 116-N-3 subsurface closeout soils Because it is reasonable to assume that the COCs in the subsurface soils will be no more variable than the COCs in the surface soil, the same number of closeout samples will be collected for subsurface closeout and backfill as for surface soil closeout. Samples will be collected from randomly determined locations and the same statistical analyses will be performed. The primary difference is that subsurface decisions have different closeout criteria.
Design F: 120-N-1, 120-N-2, and 100-N-58 site closeout As specified in Section B4.3.3 of the closure plan (Appendix B of DOE-RL [1998a]), two samples will be collected from the northern part of the units. As agreed to at a global issues meeting with the regulators (BHI 1999a), the Washington State Department of Ecology (Ecology) requested that the soil samples be collected from the spill area in the northeast corner of the site at a location and depth to be determined (with the concurrence of Ecology) based on a review of the existing data. This determination will be made considering site conditions after the pond liner has been removed. The new data, combined with the sampling data from the 1992/1993 sampling (Section B4.3.1 of the closure plan [DOE-RL 1998a]), will be sufficient to determine if remediation is complete and if closeout of the site is appropriate.
Design G: 120-N-1, 120-N-2, and 100-N-58 pipeline Because the pipeline is located 12.2 m (40 ft) underground, only two ends of the pipeline are accessible. Random sampling is not a feasible alternative, so samples will be taken from each end of the pipeline. It is reasonable to expect that contamination in the pipeline is fairly uniformly distributed throughout the pipeline. The 95% UCL on the mean of these two samples will be compared to the RAG for each contaminant. If the 95% UCL is below the RAG, then the pipeline will be left in place. If the 95% UCL is above the RAG, then the pipeline will be removed and disposed in an appropriate disposal facility.
Design H: Transition zone downstream of first dam, 116-N-3 Trench To find the transition from the contaminated to the uncontaminated section of the 116-N-3 Trench, the following steps will be taken. The first three cover panels behind the first dam will be caved in and a total of 12 soil samples[b] will be systematically taken, with four samples taken from the center of the trench below each of the three panels. The 95% UCL will be calculated for the 12 samples for all COCs. The RESRAD model will be used to calculate the mrem/yr dose above background. If the dose is below 15 mrem/yr above background, then this and the remaining sections of the trench will be declared clean and no further sampling and analysis of the trench will be required. However, if the dose is greater than 15 mrem/yr above background, then this section will be treated as contaminated. The next three cover panels will be caved in and 12 additional samples will be taken in the same manner. This process will be repeated until a section spanned by three cover panels meets the closeout criteria.

[a] After the closeout/verification samples are collected and analyzed, the assumptions of the statistical test (in this case, the t-test) must be tested to determine if the test is appropriate for the data collected. If the test is not appropriate (e.g., underlying assumptions about the statistical test are not true because the data are not normally distributed, or the data are correlated), a different statistical test may be selected (e.g., a non-parametric test, such as Wilcoxon test). In this case, the number of samples calculated by the equation may not be adequate for the alternative statistical test because it is based on the t-test. The 10-sample minimum is based on a judgment that it is the smallest sample number that would allow alternative testing of the hypothesis. However, there is no guarantee that 10 samples will be adequate, and additional samples may need to be collected.

[b] Lacking pilot study data to calculate the population variance and, from it, the number of verification samples, 12 samples were determined to be a reasonable number that should allow testing of the hypothesis.

The mathematical formula expressions needed to solve the design problems are identified in Table 7-5.

Table 7-5. Mathematical Formula Expressions Needed to Solve Design Problems. (2 pages)

Decision	Null Hypothesis	Method for Testing the Hypothesis	Formula for Number of Samples
2. Determine if debris from nonradioactive sites (120-N-1, 120-N-2, and 100-N-58) meets requirements for disposal in onsite inert/demolition waste landfills or if alternate disposal options need to be considered.	The debris exceeds criteria for disposal in inert/demolition waste landfills.	Each debris type from the 120-N-1, 120-N-2, and 100-N-58 sites will be randomly sampled at two locations for dangerous waste determination.	Data are lognormally distributed. Cohen's adjustment (as described by Ecology [1993]) used to obtain an estimate of the standard deviation of previously collected data (Appendix B of DOE-RL [1998a]).
3. Determine if data are within PRGs and support site closeout.	The waste sites contain contaminants at concentrations that exceed cleanup levels.	<u>Shallow zone soils</u>: 95% UCL on the true population mean, calculated from the sampling data. <u>Deep zone soils</u>: 95% UCL on the true population mean, calculated from the sampling data.	$n_d = \sigma^2\left\{\frac{z_{1-\beta}+z_{1-\alpha}}{C_s-\mu_1}\right\}^2+\frac{1}{2}(z_{1-\alpha})^2$ (see note a)
4. Determine if overburden/ layback soil contamination levels are above PRGs and support use as backfill.	The overburden/layback soil contains contaminants at concentrations that exceed cleanup levels.	<u>Overburden/layback soil for shallow zone backfill</u>: 95% UCL on the true population mean, calculated from the sampling data. <u>Overburden/layback soil for deep zone backfill</u>: 95% UCL on the true population mean, calculated from the sampling data.	

Table 7-5. Mathematical Formula Expressions Needed to Solve Design Problems. (2 pages)

Decision	Null Hypothesis	Method for Testing the Hypothesis	Formula for Number of Samples
7. Determine if contamination levels in the soil in the transition zone near the first dam are below PRGs and support cessation of remedial action beyond this transition zone.	The soil contains contaminants at concentrations that exceed cleanup levels.	95% UCL on the true population mean, calculated from the sampling data.	

[a] Equation taken from *Guidance for the Data Quality Objectives Process*, EPA QA/G-4 (EPA 1994b), where:

σ = the standard deviation; if no data are available, value can be estimated by dividing the range by 6 (EPA 1989). The data must be normally distributed to use this estimate.

$Z_{1-\alpha}$ and $Z_{1-\beta}$ = the critical values for the normal distribution with probabilities of $1-\alpha$ and $1-\beta$, respectively (.95 and .80 for this calculation).

C_s = the cleanup standard, which will be the limit in Table 5-3.

μ_1 = the true mean concentration (less than the cleanup standard value) where the probability is no greater than 0.20 of deciding the site does not meet the cleanup standard. In other words, μ_1 is the lower bound of the "gray region."

The use of this equation requires that (1) the data are normally distributed, (2) the data are statistically independent (not correlated), (3) that a valid estimate of the variance of the data (σ^2) is available to use in the formula, and (4) the data are obtained by a probability-based sampling design.

Often the model will describe the components of error or bias that are believed to exist in the measured values. For example, if a mean concentration of a COPC will be measured by a field screening instrument rather than through laboratory analyses, the model that relates the field screening results to the concentration results must be specified, along with any assumptions upon which the model is based. The relationships and assumptions between true and measured values are identified in Table 7-6.

Table 7-6. Relationships and Assumptions Between True and Measured Values.

Decision	Relationship Between True and Measured Values	Assumptions
Not applicable. Only analytical laboratory data will be used for site closeout decisions.		

A cost function is then developed that relates the number of samples to the total cost of sampling and analysis. The cost functions developed here will be used in the next step as part of the trade-off analyses that will be performed to determine the optimal number of samples. The costs that should be considered include, but are not limited to, mobilization, sample collection, and sample analysis costs.

Table 7-7 includes the calculation of the number of samples for each design alternative. Using the equations outlined in DQO Step 3, the number of samples for each design alternative is calculated. The Type I and Type II error rates (and other inputs in the equations) are varied to examine the relationship between the number of samples and the inputs.

Sample sizes will be calculated after field screening data provide estimates of the population variances for the COCs. With these estimates of the variances, it is inappropriate to calculate the number of samples needed for closeout.

Table 7-7. Calculation of Theoretical Number of Samples for Each Design Alternative.

Estimated standard deviation = Range/6 Lower bound of gray region = 80% of action level			
	$\beta = 0.10$	$\beta = 0.20$	$\beta = 0.25$
$\alpha = 0.01$	---	---	---
$\alpha = 0.05$	---	---	---
$\alpha = 0.10$	---	---	---

$$n_d = \sigma^2 \left\{ \frac{z_{1-\beta} + z_{1-\alpha}}{C_s - \mu_1} \right\}^2 + \frac{1}{2}(z_{1-\alpha})^2$$

Equation taken from *Guidance for the Data Quality Objectives Process*, EPA QA/G-4 (EPA 1994b), where:

σ = the standard deviation.
$Z_{1-\alpha}$ and $Z_{1-\beta}$ = the critical values for the normal distribution with probabilities of $1-\alpha$ and $1-\beta$, respectively.
C_s = the cleanup standard, which will be the limit in Table 5-3.
μ_1 = the true mean concentration (less than the cleanup standard value) where the probability is no greater than 0.20 of deciding the site does not meet the cleanup standard. In other words, μ_1 is the lower bound of the "gray region."

The use of this equation requires that (1) the data are normally distributed, (2) the data are statistically independent (not correlated), (3) that a valid estimate of the variance of the data (σ^2) is available to use in the formula, and (4) the data are obtained by a probability-based sampling design.

Several trade-offs should be considered when determining the optimal number of samples for the given budget. It is important to consider trade-offs so contingency plans can be developed and the added value of selecting one set of considerations over another can be quantified. The results of these trade-off analyses may lead to the re-examination of the DQO outputs developed to this point.

Considerations should include measurement techniques (e.g., field screening, the use of surrogates, and fixed laboratory analysis by more than one method), statistical inputs (varying the width of the gray region or Type I and Type II error rates), and other factors (e.g., spatial and temporal boundaries or scope of the project). Table 7-8 provides the results of the trade-off analysis.

Table 7-8. Results of Trade-Off Analysis.

An estimate of the number of samples needed to characterize each stratum cannot be made at this time. The recommended approach to verification sampling is to collect preliminary screening samples and analyze them using gamma energy analysis. Then, using the equation shown in Table 7-7, calculate the number of verification samples that should be collected. This strategy has worked in past remediation in the 100 Areas.

The design options are then evaluated based on cost and ability to meet the DQO constraints. The results of the trade-off analyses should lead to one of two outcomes: (1) the selection of a design that most efficiently meets all of the DQO constraints, or (2) the modification of one or more outputs from DQO Steps 1 through 6 and the selection of a design that meets the new constraints. Table 7-9 identifies the selection of the appropriate data collection design.

Table 7-9. Selection of Appropriate Data Collection Design.

Decision	Type of Design	Optimum Number of Samples
1 and 5	Judgmental	Based on professional judgment.
2	Statistical	Sample number calculated based variance of limited field investigation (Appendix B, DOE-RL [1998a]).
3 and 4	Statistical	Actual sample number calculated based on stratum-specific variance developed from field screening data.
6	Judgmental	One sample collected from each end of the pipeline.
7	Systematic	12 samples.

An outline of alternative strategies is presented in Table 7-10.

Table 7-10. Outline of Alternative Strategies.

Decision	Alternative
3 and 4	If the analytical results are not sufficient to demonstrate that cleanup levels are met based on sample design, a combination of statistical analysis, professional judgment, and balancing factors (agreed to by the regulators) will be used to determine if the site should be further excavated.

Table 7-11 lists the key features of the selected design.

Table 7-11. Key Features of Selected Design.

Decisions 2, 3, and 4	Strata of interest should be randomly sampled.

Table 7-12 documents the theoretical assumption.

Table 7-12. Documentation on Theoretical Assumptions.

Decision 2	Assumes that data are lognormally distributed, as documented in DOE-RL (1998a).
Decisions 3, 4, and 7	No assumptions have been made regarding the data. Distribution of data will be determined based on field screening data.

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APPENDIX A

ISOTOPIC RELATIONSHIPS IN THE 100 NR-1 OPERABLE UNIT WASTE STREAM

DISCLAIMER FOR CALCULATIONS

The calculations that are provided in this appendix are included for reference only. Use of these calculations by persons who do not have access to all of their pertinent factors could lead to incorrect conclusions or assumptions.

Before applying these calculations to work activities or projects outside the context of this report, these calculations must be thoroughly reviewed with appropriate and authorized Hanford Site ERC personnel. Without this review, the ER Project cannot assume any responsibility for the use of these calculations.

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CALCULATION COVER SHEET

Project Title: Remedial Action/Waste Disposal **Job No.** 22192
Area: 100 NR-1 Operable Unit
Discipline: Environmental Engineering ***Calc. No:** 0100N-CA-V0019
Subject: Isotopic Relationships in the 100 NR-1 Operable Unit Waste Stream
Computer Program: N/A **Program No.** N/A

Committed Calculation ☑ **Preliminary** ☐ **Superseded** ☐

Rev.	Sheet Numbers	Originator	Checker	Reviewer	Approval	Date
00	10	S. K. De Mers	J. C. Wiles	S. L. Winslow	A. R. Michael	1/3/2000

SUMMARY OF REVISION

Scanned:	Rev.	Date	Bar Code No.	Rev.	Date	Bar Code No.

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CALCULATION SHEET

Originator: S. K. De Mers	**Date:** 12/28/99	**Calc. No.** 0100N-CA-V0019	**Rev. No.** 00
Project: Remedial Action & Waste Disposal	**Job No.** 22192	**Chk:**	**Date:** 12/28/99
Subject: Isotopic Relationships in the 100 NR-1 Operable Unit Waste Stream			**Sheet No.** 1 of 9

The Remedial Action/Waste Disposal Project (RAWD) will be remediating waste sites in the 100 NR-1 Operable Unit. These waste sites present a unique challenge to current remedial action practices in that the residual radioactive material in the waste site will cause high background radiation. This will make it difficult to provide real time analysis of the waste unless the radioactivity from that waste can be tied to the dose rates detected in the waste. This calculation is to estimate that relationship for each milli-roentgen (mR) of gamma radiation detected.

Assumptions:

1) The principal source of gamma radiation is from the decay of ^{60}Co and ^{137}Cs (^{137m}Ba).

2) The data obtained from Table 5-6 & 5-8 of BHI-01271, *Data Summary Report for the 116 N-1 and 116 N-3 Facility Soil Sampling to Support Remedial Design*, can be used to developed the relationship of the isotopes present.

3) The relationships of isotopes that are contained in the reactor's fuel can be estimated based on Table C-17, *Selected Radionuclides in Burned Hanford Site Fuel After 40-Year Decay,* of DOE/RL-95-34, *118 B-1 Burial Ground Excavation Treatability Test Report*. The relationships in this table will have to be altered to a 12-year vice a 40-year decay.

4) "N" reactor last operated on January 7 1987 and the sampling done in Assumption #1 was done in December 1998. Therefore, the decay and ingrowth time is set at 12 years.

5) Hard to detect isotopes such as ^{241}Pu can be determined based on the detectable activity of a parent or daughter isotope.

6) ^{240}Pu activity can be combined with ^{239}Pu activity as the energies of the alpha particles emitted from both isotopes is very similar and difficult to tell apart in laboratory analysis. Most laboratories report the activities of these isotopes as $^{239/240}$Pu.

7) The activity of ^{60}Co and ^{137}Cs (^{137m}Ba) can be combined as "equivalent" ^{60}Co activity for dose rates.

8) MICROSHIELD Ver. 5.03 and RADECAY Ver. 3.01 may be used in the establishment of dose rates and isotopic relationships.

9) All sources of radioactivity within the waste stream originated in the reactor and production was stopped, other than ingrowth from decay, when the reactor was shutdown.

10) The dose rate at one foot from any source can be determined using the formula 6CNE, where C is the curies present, N is the number/abundance of the gamma ray/s and E is the energy of the gammas.

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To establish the relationships of the various isotopes in the 100 NR-1 waste stream and relate them to a dose rate, the first step is to establish the isotopes, which will significantly contribute to the gamma dose rate.

There are several isotopes in the waste stream that would contribute to the gamma dose rate. They are ^{60}Co, ^{137}Cs (^{137m}Ba), ^{154}Eu, ^{155}Eu and ^{241}Am. However, because ^{154}Eu, ^{155}Eu and ^{241}Am have concentrations about two orders of magnitude below those of ^{60}Co and ^{137}Cs (^{137m}Ba), they will be considered insignificant in their gamma dose rate contribution. A comparison of the energies and abundance of the gammas emitted from ^{60}Co and ^{137}Cs (^{137m}Ba) shows the contribution of the gamma ray from ^{137}Cs (^{137m}Ba) to be about 23.7% of the gamma ray energy from ^{60}Co. Using the formula 6CNE, where C is the curies present, N is the number/abundance of the gamma ray/s and E is the energy of the gammas, we show the following relationship. For comparison purposes, C is one curie and is used for each isotope.

$$6CNE = Dose\ Rate\ in\ R/hr\ at\ 1\ foot$$

$$6CNE\ (Ba137m) = 6 * 1\ Curie * Photon\ Abundance\ (0.8998) * Energy\ (0.66165\ MEV) = 3.57\ REM\ at\ 1\ foot$$

$$6CNE\ (Co60) = 6 * 1\ Curie * Photon\ Abundance\ (2) * Energy\ (\frac{1.1732 + 1.3325}{2})\ MEV = 15.03\ REM\ at\ 1\ foot$$

$$\frac{3.57 \cdot REM}{15.03\ REM} = 0.237$$

From this, we can use the factor 0.237, to multiply times the ^{137}Cs (^{137m}Ba) activity to determine its equivalent activity to that of ^{60}Co. Adding these two contributions together (the activity of ^{60}Co and the activity of ^{137}Cs (^{137m}Ba) times 0.237), will give the total expected dose rate based on equivalent ^{60}Co activity.

This relationship is shown in the table on the next page for ^{137}Cs (^{137m}Ba) and ^{60}Co and their combined dose rates for the 116 N-3 waste stream. The values listed for Cs137 in the lower table have a correction factor applied of 0.237 to equate their activity to Co60.

The top portion of the table lists the activities for the major gamma emitting isotopes for RCF and for TMA. They also include the actual dose rates, and a dose rate from a MICHROSHIELD model using the actual weights and activities. Attachment 1 shows a typical model for the TMA sample #BOTBY0.

This was done for comparison purposes. The results are listed in the last line of the bottom table where the average equivalent Co60 activity is listed that would yield one milli-rem per hour of dose rate. The actual dose rates listed are the ones measured in the field, 1 cm from the sample containers.

Using all values for estimating activity, 2,720 pCi/gm equivalent ^{60}Co would be used to roughly equate to a 1.0 mR/hr dose rate from a large sample volume (trackhoe bucket).

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116 N-3 Test Pit Data

2.0-3.5 feet

RCF
HEIS# BOTC10
RCF # 5077, Sample Volume = 20 ml

Isotope	*Activity* pCi/gm	*Model Dose Rate* mR/hr	*Actual Dose Rate* mR/hr
Cs137	1.60E+04		

TMA
HEIS # BOTBY0
TMA # N901012-01, Sample Volume = 120 ml

Isotope	*Activity*	*Model Dose Rate*	*Actual Dose Rate*
Co60	2.58E+04	6.2	8
Cs137	8.39E+03		

3.5-4.5 feet

RCF
HEIS# BOTC11
RCF # 5078, Sample Volume = 20 ml

Isotope	*Activity* pCi/gm	*Model Dose Rate* mR/hr	*Actual Dose Rate* mR/hr
Cs137	5.60E+03		

TMA
HEIS # BOTBY1
TMA # N901012-02, Sample Volume = 120 ml

Isotope	*Activity*	*Model Dose Rate*	*Actual Dose Rate*
Co60	5.07E+03	1.3	2
Cs137	3.08E+03		

4.5-6.0 feet

RCF
HEIS# BOTC12
RCF # 5079, Sample Volume = 20 ml

Isotope	*Activity* pCi/gm	*Model Dose Rate* mR/hr	*Actual Dose Rate* mR/hr
Cs137	6.80E+03		

TMA
HEIS # BOTBY2
TMA # N901012-03, Sample Volume = 120 ml

Isotope	*Activity*	*Model Dose Rate*	*Actual Dose Rate*
Co60	7.24E+03	1.9	3
Cs137	4.39E+03		

Co60	Cs137	pCi/mr	mr/hr
5.30E+04	3.79E+03	2.84E+03	20
1.60E+04	1.33E+03	3.77E+03	4.6
9.00E+03	1.61E+03	1.54E+03	6.9
2.60E+04	2.24E+03	2.71E+03	10.5

Co60	Cs137	pCi/mr	mr/hr
2.58E+04	1.99E+03	3.16E+03	8
5.07E+03	7.30E+02	2.42E+03	2
7.24E+03	1.04E+03	2.59E+03	3
1.27E+04	1.25E+03	2.72E+03	4

CALCULATION SHEET

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Project: Remedial Action & Waste Disposal	Job No. 22192	Chk:	Date: 12/28/99
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$^{239/240}$Pu

To establish the relationship between the equivalent ^{60}Co and the $^{239/240}$Pu present, sample data was used. The average sample activity for $^{239/240}$Pu from the test pit data, Table 5-8 of BHI-01271, *Data Summary Report for the 116 N-1 and 116 N-3 Facility Soil Sampling to Support Remedial Design* shows the levels of 46.4, 11.2 and 13.3 pCi/gm per mR/hr for an average of 23.6 pCi/gm per mR/hr. From the same data, ^{241}Am showed 25.7, 5.58 and 6.56 pCi/gm per mR/hr for an average of 12.6 pCi/gm per mR/hr.

To relate the hard to determine isotopes, the following relationships are provided.

^{241}Pu

^{241}Pu gives off a low energy beta and can only be determined using exotic and expensive laboratory techniques. Its daughter product, ^{241}Am, can be easily detected in a laboratory either by a Gamma Energy Analysis (GEA) or by an Alpha Energy Analysis (AEA). Therefore if a relationship between ^{241}Pu and ^{241}Am can be estimated then no special laboratory analysis need be performed. To determine this relationship, one curie of ^{241}Pu is decayed for 12 years, the time between the reactor shutdown and the sampling done in December 1998. Using the RADECAY model, the decayed results show the ^{241}Pu activity would have decayed to 0.56123 curies. The build up of ^{241}Am would be 0.014465 curies. Dividing these two numbers together would yield a conservative ratio of ^{241}Pu to ^{241}Am.

$$\frac{0.56123\ curies\ Pu241}{0.014465\ curies\ Am241} = 38.8$$

Therefore, to determine the activity of ^{241}Pu, multiply the ^{241}Am activity by 38.8. This is a conservative approach as the more time that passes, the smaller this multiplier becomes. For example, after a 40-year decay, the multiplier would be 5.34 versus 38.8.

Other Isotopes

Other isotopes that have been detected or postulated in 100 area waste streams need to be addressed.

^{233}U

^{233}U is created by the decay of ^{233}Th, also an isotope with a short half-life (22.3 minutes). ^{233}Th is created when ^{232}Th is bombarded with neutrons. Although not normally used in Hanford reactors, some effort was made to create ^{233}U using ^{232}Th targets and therefore cannot be discounted. Like ^{240}Pu, ^{233}U is hard to distinguish between it and ^{234}U. Therefore, the activities of both will be reported together as $^{233/234}$U.

CALCULATION SHEET

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^{237}Np

^{237}Np is developed in the reactor waste stream by the decay of ^{237}U and by the decay of ^{241}Am. The decay from ^{241}Am is easy to establish as we know how much ^{241}Am is present and the program RADECAY can determine the relationship between ^{241}Am and ^{237}Np. Decaying 1 pCi of ^{241}Am for 12 years shows there are 3.85E-7 pCi's of ^{237}Np for 1 pCi of ^{241}Am. This is not a significant source of ^{237}Np.

The contribution to ^{237}Np from the decay of ^{237}U is harder to determine as we do not know how much ^{237}U was created in the reactor that then decayed to ^{237}Np. ^{237}Np is relatively easy to detect and the waste profile for this waste stream lists 22 pCi/gm as its highest known value. This will be assumed to be the value when a dose rate of 1.0 mR/hr is detected and then scaled up from there as the dose rate changes.

^{242m}Am & ^{234}Am

^{242m}Am & ^{234}Am are produced in the reactor by adding neutrons to Am241 and/or by the decay of ^{243}Pu. There currently is too little information on how to develop a relationship between ^{242m}Am & ^{234}Am and ^{241}Am. Therefore to conservatively predict the levels of ^{242m}Am & ^{234}Am, it will be assumed that the mass of ^{242m}Am & ^{234}Am, will be the same mass as that of ^{241}Am. The activity of ^{241}Am when the dose rate is 1 mR/hr has been determined to be 12.6 pCi/gm. The mass of ^{241}Am, as determined by its activity, for this dose rate is 3.67 E-12 gms. When this value is applied to ^{242m}Am, the activity is 36 pCi/gm and when applied to ^{243}Am the activity is 0.74 pCi/gm.

^{238}Pu

^{238}Pu may be detected by laboratory analysis via an AEA. However, based on the data in the C-17 table listed in Assumption #3, and reverse decaying the value for 12 years instead of 40 years, a multiplier of 0.06 can be used. This factor is multiplied by the ^{239}Pu activity to come up with the ^{238}Pu activity.

CALCULATION SHEET

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^{244}Pu

^{244}Pu is created in the reactor by adding neutrons in a series from ^{239}Pu. ^{244}Pu may be detected by measuring the gamma energies of one of its daughter products, ^{240m}Np as it would be in secular equilibrium with ^{244}Pu after twelve years of decay. However, the activity would have to be high enough to be detectable by a gamma energy analysis. Without any other data available, the level of ^{244}Pu has to be determined from neutron activation as follows:

1) The fuel was left in the reactor long enough that there was about a 10% in-growth of ^{240}Pu after the development of the desired product, ^{239}Pu. The measured activities of the ^{239}Pu and ^{241}Am show this to be a fair approximation when their activities are converted to mass.

2) The 10% conversion by mass continues from ^{240}Pu all the way to ^{244}Pu. When complete and when correcting the mass change for known activity, the mass of ^{244}Pu when the ^{239}Pu activity is 23.6 pCi/gm is 4.65 E-15 gms. Converting this to an activity of ^{244}Pu gives a value of 9.24E-08 pCi/gm.

^{243}Cm, ^{244}Cm, ^{245}Cm, ^{246}Cm, ^{247}Cm & ^{248}Cm

^{243}Cm, ^{244}Cm, ^{245}Cm, ^{246}Cm, ^{247}Cm & ^{248}Cm are postulated to exist in the waste stream, but detecting them is difficult and expensive. The values to be used for each mR/hr for the Curium chain, are the ones listed in the waste profile with the exception of ^{244}Cm which has been detected by the radiological counting facility. When using the methods of detected concentrations to dose rates from samples, the detected ^{244}Cm shows a value of 0.55 pCi/gm for each mR/hr. Sample data: sample #BOTC18 with 5.1 pCi/gm ^{244}Cm, sample # BOTC19 with 33 pCi/gm ^{244}Cm, sample BOTC20 with 6.1 pCi/gm and sample # BOTC21 with 460 pCi/gm ^{244}Cm. The dose rates on these samples were 60, 80, 100 and 400 mR/hr respectively.

^{99}Tc, ^{234}U, ^{235}U & ^{238}U

^{234}U, ^{235}U & ^{238}U can be determined in the same way as ^{238}Pu. The table listed above shows a relationship of 0.007 curies of ^{99}Tc, ^{234}U and ^{238}U for each curie of ^{239}Pu. For ^{235}U, it lists a relationship of 0.0003 curies of ^{235}U for each curie of ^{239}Pu. Do to the long half-lives involved, no compensation for decay was done.

^{3}H, ^{63}Ni ^{14}C & ^{59}Ni

^{3}H, ^{63}Ni ^{14}C & ^{59}Ni are also difficult to detect isotopes. Table C-17 list relationships for these isotopes are well. The table lists a factor of 0.17 curies of ^{3}H for each curie of ^{239}Pu. Compensating for decay, the factor is corrected to 0.819. For ^{63}Ni, the table lists a factor of 0.03, compensating for decay it becomes 0.0367. For ^{14}C and ^{59}Ni, the factors listed in the table (0.002-^{14}C and 0.0003-^{59}Ni) are used as they, like Uranium have a long half-lives.

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^{90}Sr, ^{154}Eu & ^{155}Eu

^{154}Eu & ^{155}Eu have all been detected in the waste stream and their ratios to the equivalent ^{60}Co value is determined based on their detected value compared to the same value for the equivalent ^{60}Co for the same sample. The only sample data showing values for europium is the analysis performed at the radiological counting facility for samples taken from the 116 N-3 crib. There are only two sample results for ^{154}Eu and only one result for ^{155}Eu. The sample activity is dividing by the dose rate from the sample to give a ratio of pCi/gm to mR/hr. Sample #BOTC18 had 1,900 pCi/gm ^{154}Eu and the sample had a dose rate of 60 mR/hr. Sample # BOTC21 had an activity of 43,000 pCi/gm ^{154}Eu and 8,000 pCi/gm ^{155}Eu and this sample read 400 mR/hr. To start we will only use the data from the second sample. Therefore, for ^{154}Eu, a ratio of 107.5 pCi/gm per mR/hr is established and for ^{155}Eu a ratio of 20 pCi/gm per mR/hr is established.

For ^{90}Sr, values were detected in three samples from the trench and can be compared to the dose rate to find a ratio to equivalent ^{60}Co. Only the trench data is used, as the dose rates taken are for the samples themselves when prepared for shipment. The dose rates for the crib samples when prepared for shipment are not available. The samples are: BOTBY0, which had 853 pCi/gm ^{90}Sr; BOTBY1, which had 371 pCi/gm ^{90}Sr and BOTBY2, which had 408 pCi/gm ^{90}Sr. These samples read 8.8, 2.4 and 3.2 mR/hr respectively. This gives an average value of 126 pCi/gm for each mR/hr.

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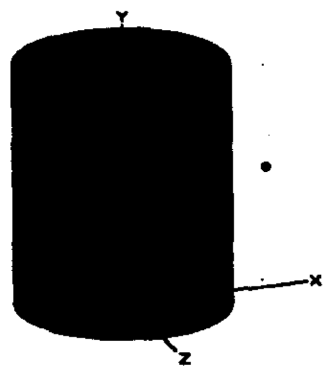
Attachment 1 MICROSHILED RUN

MicroShield v5.03 (5.03-00002)
Bechtel Hanford, Inc.

Page : 1
DOS File: BOTBY0.MS5
Run Date: December 28, 1999
Run Time: 7:12:05 AM
Duration: 00:00:05

File Ref: N/A
Date:
By:
Checked:

Case Title: Case 1
Description: Case 1
Geometry: 7 - Cylinder Volume - Side Shields



Source Dimensions

Height	6.0 cm	2.4 in
Radius	2.5 cm	1.0 in

Dose Points

	X	Y	Z
# 1	3.5 cm	3 cm	0 cm
	1.4 in	1.2 in	0.0 in

Shields

Shield Name	Dimension	Material	Density
Source	117.81 cm³	Concrete	1.9
Transition		Air	0.00122
Air Gap		Air	0.00122

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels	μCi/cm³	Bq/cm³
Ba-137m	1.7763e-006	6.5722e+004	1.5077e-002	5.5786e+002
Co-60	5.7688e-006	2.1345e+005	4.8967e-002	1.8118e+003
Cs-137	1.8777e-006	6.9473e+004	1.5938e-002	5.8971e+002

Buildup
The material reference is : Transition

Integration Parameters

Radial	10
Circumferential	10
Y Direction (axial)	20

Results

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0318	1.361e+03	4.372e-02	9.988e-02	3.642e-04	8.320e-04
0.0322	2.510e+03	8.393e-02	1.949e-01	6.755e-04	1.568e-03
0.0364	9.135e+02	4.549e-02	1.242e-01	2.585e-04	7.059e-04
0.6616	5.914e+04	1.928e+02	2.422e+02	3.739e-01	4.695e-01
0.6938	3.482e+01	1.197e-01	1.491e-01	2.311e-04	2.879e-04
1.1732	2.134e+05	1.312e+03	1.528e+03	2.344e+00	2.730e+00
1.3325	2.134e+05	1.508e+03	1.733e+03	2.617e+00	3.007e+00
TOTALS:	4.908e+05	3.013e+03	3.504e+03	5.336e+00	6.210e+00

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Attachment 2 – Decay Chain

Isotopes highlighted in bold are the main stream created by neutron activation.
The 1 to 1 term means the parent and daughter are in secular equilibrium
Arrows either ^ or > indicate the direction of decay or activation.
Where no arrow is indicated, the direction of decay is down.
Next to the method of decay is a number indicating the ratio of the parent to the daughter.
If a % is listed then the parent has completely converted to the daughter/s.

Rx Fuel

					Pa233
				^	α 1 το 1
	Th231		Th232		Np237
^	α 1 το 1	^	α ε–9	^	β 100%
	U235	**>n**	***U236***	**>n**	***U237***

			Rx	**Targets**				U234		U235		U236		Am241		U238		Am243		U240
							^	α ε–4	^	α ε–8	^	α ε–6	^	β 0.026	^	α 2ε–9	^	β 100%	^	β 1 το 1
								Pu238		Pu239		Pu240		Pu241		Pu242		Pu243		Pu244
							^	α 0.005	^	α 4ε–4	^	α 1.6ε–3	^	α 0.44	^	α 2ε–5	^	α 1 το 1	^	α 9ε–8
		Th231		Th232		Np237		***Cm242***	**>n**	***Cm243***	**>n**	***Cm244***	**>n**	***Cm245***	**>n**	***Cm246***	**>n**	***Cm247***	**>n**	***Cm248***
	^	α ε–7	^	α ε–9	^	α ε–6	^	***β 83%***		ε 3ε–6										
		U235		U236		***Am241***	**>n**	***Am242***	>n	Am243		U240								
	^	α ε–8	^	α ε–6	^	***β .026***	^	ε 17%	^	β 100%	^	β 1 το 1								
		Pu239	**>n**	***Pu240***	**>n**	***Pu241***	>n	Pu242	>n	Pu243	>n	Pu244								
	^	***β 100%***	^	β 100%				α 2ε–9												
		Np239		Np240m				U238												
	^	***β 100%***	^	β 100%																
U238	**>n**	***U239***	>n	U240																

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